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A DIGEST OF
INDUSTRIAL WASTE TREATMENT

By

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April - 1940

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When the preparation of a manual on treatment of industrial wastes was first considered, the assignment appeared impossible to fulfill. There are so many variables and differences of opinion in this relatively immature phase of the sanitary engineering field that, even though many more or less successful waste treatment works have been installed, standard methods and factors of design have not been established for treatment of a number of kinds of industrial wastes. Furthermore, the art of industrial waste treatment is in such a state of flux, with new methods of treatment being proposed on every hand, that practices considered standard at the moment may become obsolete in a very short time.

It is important, also, that engineers engaged in solving industrial waste problems realize that, whereas public sewage is ordinarily considered as rather uniform in quantity and analytical characteristics for a given population, industrial wastes from even a single establishment among the many different kinds to be considered, as affected by modifications in industrial practices and processes, may change so quickly and decidedly that analytical and quantitative data collected only a short time ago are not dependable for application to the study of new problems.

In attempting to summarize current knowledge concerning treatment of industrial wastes common in Pennsylvania, I shall not presume to arbitrarily advise in any detail with respect to problems which do not appear to be reasonably solved by established practice. I shall recommend particular methods of treatment and factors of design only with respect to those waste waters whose treatment has become fairly well conventionalized. Otherwise, this paper will simply discuss problems and cite or suggest methods of treatment which have been or may be employed.

It seems appropriate to add that designing engineers or industrial managements quite often propose the utilization of novel methods for the solution of waste water problems and that in general, if the proposed methods appear to be based on sound principles, it is proper to recommend the issuance of a permit containing a condition to the effect that the installation shall be regarded as experimental with final approval dependent on the results attained in actual performance.

Before plunging into consideration of specific wastes, it will be well to review the qualities of industrial wastes which are ordinarily recognized as objectionable. These are: putrescibility, acidity or causticity, toxicity, color, taste, odor, settleable solids, turbidity and oil. The proper consideration of these factors will include their effect on public health, animal or aquatic life, water works for domestic or industrial consumption and recreation.

Since the waste water discharges from different industrial establishments manufacturing identical products may differ widely as to quantity and quality, because of variations in processes and differences in plant housekeeping, it is almost always advisable to have careful analytical survey made of the waste waters as well as to know the analytical characteristics of the receiving stream during periods of low stream stage, before reaching conclusions as to the harmful effects of specific discharges or the adequacy of proposed waste treatment works.

The degree of treatment required in any particular instance should be dependent on the use and condition of the receiving stream but, in general, certain standards of purity of streams are now quite well established. Probably the most generally accepted standards are those proposed by H. W. Streeter (1) (U.S.P.H.S.) in which an average minimum of 3.0 to 4.0 p.p.m. dissolved oxygen and a maximum 5-day B.O.D. of 4 p.p.m. in the receiving stream, is suggested, with remark that the trend is toward even higher D.O. concentration and limitation of B.O.D. to definitely assure, at all times, a positive oxygen balance, or excess of available oxygen over oxygen demand. These figures are consistent with recommendations of the Tri-State Commission for the Abatement of Pollution of Harbor and Coastal Waters within the Metropolitan Area of New York City, which state that waters used for recreational purposes should have dissolved oxygen content above 50% at all times. Robert Spurr Weston (2) generalizes by stating that "each stream*****must be used for the best interests of all riparian owners and with due regard to the right and convenience of all."

With respect to study of the volume and character of individual industrial wastes, it seems well to quote Weston (3) who is recognized as an authority. He states: "While much may be gotten from the literature and from experience, each case is 'sui generis', peculiar and variable. *** The minimum for a beginning is to *** arrange a typical day of maximal operation and then sample and analyze everything in sight. In this

examination, variation in strength should be determined by frequent sampling and determinations, while integrated (proportionate composite) samples representing parts of the whole day may be taken for general analysis. It is wise to make more than one examination of this kind. Usually distinction between the working day and the remainder of the 24 hours must be made.

" *** The next step is to determine what wastes, rinsing waters and the like, may be discharged without treatment. *** After the purifying capacity of the stream is known and a decision is made regarding the separation of wastes, then follows the determination of the degree of purification required for remaining wastes."

Also emphasizing the need for accurate evaluation of pollution, but from a different point of view, is the statement of F. W. Mohlman, Sanitary District of Chicago, that those who have investigated industrial wastes know that the manufacturer rarely appreciates how much of his product goes down the sewer until a reliable sampling and gaging survey is made in cooperation with some public engineering bureau.

Obviously, determinations for B.O.D. and D.O. at any given time are, in themselves, not all-sufficient in the study of an industrial waste problem since inert solids, oil, color, acidity or causticity, toxicity, sludge deposits and possibly other factors are important.

The principal kinds or sources of objectionable industrial wastes encountered in Pennsylvania, with remarks as to their character, pollution effect and known methods of treatment, are here given:

ABATTOIRS AND PACKING HOUSES: In the slaughtering of animals and the preparation of meat for food purposes, great quantities of water are used and the waste waters contain much blood, grease and manure with varying quantities of fleshings, all of which are extremely heavy in pollution load.

A study (4) of 41 packing houses in the Sanitary District of Chicago indicates that their waste waters contained 5,100 pounds suspended solids and developed 5,175 pounds B.O.D. per million gallons. After preliminary sedimentation and flotation these wastes are to be accepted in the new Southwest Sewage Treatment Works.

Good practice dictates collection of blood and paunch manure and its preparation and disposal as fertilizer, and screening of waste waters for removal of the larger fleshings, hair and other solids. Good house-keeping is essential in minimizing wastes and reducing the cost of waste treatment. All scalding and washwaters should be subjected to effective sedimentation and flotation treatment for reduction of solids and grease.

Waste waters treated to this degree are successfully accepted in public sewer systems and sewage treatment works (Allentown and Reading) although difficulties might be encountered if the proportion of abattoir wastes to sewage were quite high. Regulation of discharge is advisable to prevent overloading at periods of the day. At Sioux Falls (5) (35,000 population) packing house wastes having population equivalent of 103,000 are treated in public sewage treatment works providing chemical coagulation and sedimentation of packing house wastes and plain sedimentation of sewage followed by joint trickling filter and aerating tank treatment.

Removal of 9% suspended solids is reported (6) on 20 mesh screens and 19% on 30 mesh screens, but B.O.D. is not substantially reduced by screening. Forty mesh screens are reported satisfactory in some installations. Mechanical screens are considered advisable for these wastes and large installations frequently utilize those of rotary type. High velocity water sprays are necessary to prevent rapid clogging and frequent cleaning of rotary screens with steam, hot water and soda ash is necessary, in addition to the water spray jets which operate continuously. Sedimentation in Imhoff tanks, with detention of 1 to 3 hours, is reported to remove approximately 65% suspended solids and 35% B.O.D. and to produce a sludge containing 90% moisture. The settled solids consist of about 75% volatile matter and 25% ash and contain about 2.72% nitrogen.

Chemical coagulation increases the efficiency in removal of suspended solids but produces an excessive volume of foul smelling sludge which is difficult to dry.

If the wastes treated by segregation, screening and sedimentation cannot be discharged to a public sewer system, either by reason of inaccessibility or unacceptability, further treatment will probably be necessary.

For small plants E. F. Eldridge (7) of Michigan Engineering Experiment Station suggests chlorine and ferric chloride, coagulation, agitation and fill-and-draw sedimentation with conventional drying beds for the sludge, which is approximately 8% of the total wastes in volume. Septic tank treatment is not considered successful by Eldridge and Pennsylvania experience does not favor septic tanks with tile field absorption, although such treatment might prove successful under favorable conditions if the septic tank effluent were quite free of grease. A number of small abattoirs use leaching cesspools but these frequently clog and create nuisance. Eldridge believes that the activated sludge process is too complicated for the small plant but since this process

has recently been developed to provide compact and easily controllable units there appears to be real promise of success with this method of treatment.

Trickling filters of conventional design, operating at rates varying from 0.6 to 1.0 m.g.a.d., following effective sedimentation and flotation, are reported by F. W. Mohlman (8) to operate successfully with removals of 81% B.O.D. but should be followed with secondary sedimentation for clarification which produced overall B.O.D. reduction of 88%.

Max Levine (9) of Iowa State Experiment Station reports B.O.D. reduction of 45.8% with a coarse stone trickling filter 10 feet deep and dosed at 7 m.g.a.d. without clogging. He further reports that double filtration at about 4 m.g.a.d., with settling after each stage, reduced the B.O.D. from 650 p.p.m. to 42 p.p.m., an overall reduction of 93.5%. His conclusions are that from 1,173 to 4,343 pounds B.O.D. are removed per acre foot by primary filtration and 246 to 1,362 pounds by secondary filtration, the B.O.D. load removed per unit volume of filter varying directly with the concentration and rate of application of the waste and inversely with the depth of filter. Double filtration based on Levine's studies is successfully operated at Jacob E. Decker and Sons, Mason City, Iowa.

Activated sludge treatment with pre-aeration of influent is successfully employed at the plant of the Kuhner Packing Company (10) at Muncie, Indiana, providing 98.4% overall reduction of the original B.O.D., of which about 44% is removed in the primary clarifier and the remainder by the aeration units. The B.O.D. of the raw wastes averaged about 665 p.p.m. for full 24 hour periods during tests, varying between 980 p.p.m. and 350 p.p.m. for individual days. It has been found at this plant that an average of 560 gallons of waste water is produced per hog unit, that 4.25 cu.ft. of air is used per gallon of waste treated or about 780 cu.ft. of air per pound of B.O.D. reduction, that the B.O.D. per hog unit averaged 3.14 pounds of which about 3.10 were removed by the treatment plant and that electric power used amounted to about 0.34 K.W.H. per pound of B.O.D. removed. A long aeration period (17 hours average) is provided to smooth out the organic load which is also controlled by dilution with condenser water and a high rate of return sludge from the final clarifier (90% to main aeration units and 10% to pre-aeration tank). The cost of treatment is reported to be 5.5 cents per hog unit, without taking into account the revenue from sale of grease skimmings.

Super-chlorination as practiced at the plant of the George A. Hormel Company (11), Austin, Minnesota, was proved capable of removing 80% organic nitrogen, over 98% suspended solids and over 80% B.O.D. but the hopes that the treatment plant would completely pay for itself in production of fertilizer and feed did not appear

to be realized due to criticism that the sludge did not decompose as a fertilizer and that it showed toxicity when used experimentally as feed. Also, it developed that certain wastes should be excluded to secure the desired results. However, results indicated that a satisfactory effluent could be produced at a cost not much greater than that of biological treatment.

ACID PICKLING LIQUOR: Acid solutions used for pickling ferrous metals are usually wasted when their acid content becomes reduced to approximately 2%. Rinse waters from pickling plants also contain appreciable acid. The acid effect on receiving streams from pickling plant wastes is due not only to free acid but also to the acid formed by hydrolysis of the iron salts in solution. Such discharges not only reduce or overcome natural alkalinity but also increase hardness of the receiving stream, so causing difficulties and expense in water treatment as well as harm to fish life.

New methods of metal pickling which use or waste little or no acid should be encouraged in the interest of stream sanitation, although the non-acid processes are expensive and admittedly not always applicable.

It is usually possible to effect marked savings in acid by providing thorough drainage of the metal back into the pickle tank before immersion in the rinse tank. In tubing it is important that it be tilted and held for drainage. Some strip mills which operate continuous pickling have squeegee rolls to remove excess acid as the strip leaves the pickle tank. Some mills are reported to utilize air nozzles to blow excess acid back into the pickle tank as the rods or strips are passing out.

At a number of steel works spent pickling liquors are treated by addition of scrap steel to exhaust the free acid, followed by evaporation and drying of the residue to produce commercial "Copperas" or ferrous sulfate. The limited market for ferrous sulfate prevents wider adoption of this reclamation process.

Many works neutralize the pickle liquor with lime, followed by aeration and sedimentation to complete the reaction and remove the iron oxides and salts, so eliminating free acid and minimizing iron and hardness in the effluent. In rare instances the final effluent is filtered through sand for removal of remaining hydrate floc or oxide.

The so-called Ferron (12) process for treatment of spent

pickling acid, as operated at the Sharon Steel Corporation at Sharon, provides for excess treatment with unsilicated low magnesium lime, heating and agitation and treatment of the resultant slurry in a conventional filter press for extraction of the mixture of calcium sulfate (gypsum) and iron oxide which is extruded from a pug mill in blocks. The blocks of reclaimed material are dried and made available for conversion into insulating and construction materials such as pipe covering, partition block and wall board, according to conventional methods now in use. The liquid effluent is clear, colorless and free of acid with a pH of approximately 7.5.

The Dorr Company has developed a system utilizing fine (200 mesh) limestone, crushed in a wet ball mill, for complete neutralization of all waste acid and hydrolyzable iron compounds by three-stage agitation and aeration for completion of reaction. The slurry so produced is recirculated at an adjustable rate, through the agitator compartments, for building up large particles of calcium sulfate and ferric hydroxide which will filter readily. The effluent from the agitator battery passes to a flocculator where a small quantity of starch is added to assist in clarification, after which the liquid passes through a clarifier tank. The settled solids in the clarifier are pumped to an Oliver filter for dewatering to a firm cake carrying not over 55% moisture and this cake is suitable for final disposal. The manufacturers guarantee that the final effluent will be substantially clear, alkaline to methyl orange, of pH about 6, that it will carry not over one pound per thousand gallons of insoluble material in suspension, that precipitation of the ferrous sulfate will be 98% complete and that oxidation of the ferrous iron will be more than 98% complete. A permit for construction of a treatment plant of this type in Pennsylvania will probably be issued in the near future.

Acid pickling liquor cannot safely be admitted to public sewer systems or sewage treatment works because of resultant disintegration of steel, cement or concrete, compacting of sludge, clogging of trickling filters or disturbance of reaction in activated sludge systems.

ANTHRACITE COLLIERIES: In a report (13) of the U. S. Corps of Engineers relating to the Schuylkill River, as transmitted to Congress in 1939, it is stated that more than 15% of the (anthracite) coal mined is wasted with water used in the cleaning process. It is not surprising that difficulties arise in the disposal of these large quantities of finely divided waste material. The settleable solids (displacement method—2 hours standing) has been found, by experiments within the Bureau of Engineering of the Department of Health to vary between 160 c.c. per liter in an untreated waste, and 4 c.c. per liter in a treated waste.

The settleable solids in both untreated and treated anthracite washery wastes from three typical collieries as shown at the end of various settling periods are given in the following tables:

Table No. 1

Untreated Colliery Wastes

Settleable Solids in c.c. per Liter

	<u>15 min.</u>	<u>30 min.</u>	<u>1 hr.</u>	<u>2 hrs.</u>
No. 1	160	120	97	85
No. 2	150	85	65	50
No. 3	<u>130</u>	<u>200</u>	<u>180</u>	<u>160</u>
Average	147	135	114	98

Table No. 2

Settled Colliery Wastes

Settleable Solids in c.c. per Liter

	<u>15 min.</u>	<u>30 min.</u>	<u>1 hr.</u>	<u>2 hrs.</u>
No. 1 Slush Basin Effluent	110	62	56	44
No. 2 Secondary Dorr Clarifier Effluent*	2	2	4	4
No. 3 Slush Basin Effluent	<u>0.7</u>	<u>1.5</u>	<u>3</u>	<u>6</u>
Average	38	22	21	18

Note: *Two clarifiers in series at this colliery.

The figures in these tables show that, in samples containing large quantities of solids, the maximum apparent volume of culm and silt was generally deposited in 15 to 30 minutes. It also appears that the settled solids compact considerably on standing.

The figures in Table No. 2 seem to indicate that in the case of previously but imperfectly settled colliery wastes a period longer than 30 minutes is generally required to produce maximum effective sedimentation. Sample No. 3 contained solids of such slow settleability that even a one hour period did not show maximum apparent settled solids.

These and other observations indicate that the reduction in volume in sedimentation of untreated samples, after 15 minutes and up to about 1 hour, is not a true index of compaction only but is actually compaction of coarser material combined with additional deposit of finer material and that this combined effect, as shown in Table No. 2, produced maximum practical efficiency in sedimentation for a period of about 1 to 2 hours. It should be remembered, however, that these results were secured under laboratory conditions producing absolute quiescence and that an equal period of sedimentation under actual operating conditions would not prove as effective. (The classic studies of Capen (14) of the New Jersey Department of Health indicate that to produce an average desired detention period requires a theoretical detention period three to four times as great.) Also, admitting that evaluation of solids remaining in the supernatant liquid after sedimentation would be desirable to demonstrate actual efficiency, it has been invariably observed that colliery wastes after quiescent settlement for 30 minutes to 1 hour show a supernatant which is free of visible solids but which is slightly darkened by minute suspended particles.

The most practical and efficient method of treatment of colliery wastes appears to be preliminary sedimentation in a mechanical clarifier or thickener affording about one hour's theoretical detention at low velocity, followed by final sedimentation at low velocity for a period of at least 4 hours. The preliminary sedimentation not only will recover the smallest merchantable sizes of coal but by removal of roughly 75% of the volume of settleable solids, will reduce very greatly the volume of solids deposited in the final sedimentation basin and its cost of maintenance. Slush basins, if providing ample detention and low velocities, are often suitable for final sedimentation, but they must be so located and constructed that they will not wash out to a stream due to storms or dike failures.

In a supplement to a 1937 report of the U. S. Corps of Engineers on the effects of culm and silt on the Schuylkill River, Fred H. Dechant (15) of Reading developed data from a study of waste waters from 22 collieries indicating that anthracite coal particles of 100 screen size will settle at less than about 82 feet per hour, particles at 200 size will settle at velocities slower than about 21 feet per hour, and particles of 300 size will settle at velocities below about 8 feet per hour. His studies also indicate that to provide river water with a maximum silt content of 1,000 p.p.m., suitable for ordinary and superior uses after reasonable treatment, would require removal from breaker waste water of all material which will pass through a 325 mesh screen. Such removal would, according to his graph, require limitation of velocity in sedimentation to about 7 feet per hour.

BREWERIES: The ordinary wastes from breweries are spent grain mash, spent hops, keg and bottle wash water and rinse waters from cookers, fermenters and storage or ageing vats. Mash or spent grain is ordinarily retained by fine screening and disposed of, either moist or dried, as stock feed. Hops should also be retained by screens or screen presses because the rather tough leaves and stems may clog sewers, but this material is not acceptable as stock feed. Keg and bottle wash water is not particularly objectionable if discharged to a stream affording ample dilution but the rinsings from fermenters, ageing vats and yeast recovery processes, being heavy in both living and dead yeast cells, are very high in proteins which decompose rapidly and with production of foul odors and high oxygen demand. Undiluted yeast plant wastes contain from 1 to 3 p.p.m. total solids and produce a B.O.D. (5-day) of, approximately, 7,000 to 14,000 p.p.m.

Combined brewery wastes are reported by Boruff (16) of Hiram Walker & Son to have a population equivalent of 15 to 25 per 31 gallon barrel of beer, based on 0.17 pounds 5-day B.O.D. per capita per day.

Breweries are generally located in cities provided with sanitary sewer systems and the waste waters may usually be admitted, after passage through fine screens, to such sewer systems without harm to sewage treatment processes. If the brewery is relatively large compared with the size of the sewered community, it might be advisable to regulate the discharges from fermenters and ageing vats,—particularly the latter.

If private treatment of brewery wastes is required, the method adopted would probably be similar to conventional sewage treatment utilizing sedimentation and trickling filter oxidation since, (1) chemical precipitation has been found insufficiently effective or flexible and it produces large quantities (2% to 2 1/2%) of sludge, (2) anaerobic or thermophilic digestion followed by oxidation appears to be inordinately expensive, even if it should be capable of producing a satisfactory effluent, and (3) the activated sludge process is particularly susceptible to bulking caused by brewery wastes. However, it appears possible that the activated sludge process, with load regulation and chemical adjustment, may offer a real hope of success.

Probably the most modern and complete brewery waste treatment works recently installed is that of the Gulf Brewing Company (17) at Houston, Texas. The brewery produces 1,500 barrels (31 gallons each) per day and the combined waste discharges average about 500,000 gallons per day. The B.O.D. averages 349 p.p.m. and the suspended solids 371 p.p.m. The treatment works comprises two primary and secondary settling tanks with mechanical sludge collectors, each providing 1 1/2 hour detention, primary and

secondary trickling filters each 100 feet in diameter and 6 1/2 feet deep, sludge digestion tank of 14,500 cubic feet capacity and sludge drying beds having an area of 2,080 square feet. The total cost of the works is estimated at about \$60,000 and the yearly operating charges are estimated at from \$2,400 to \$3,900.

The operation of a pilot plant which was the basis of this design showed a 90% reduction in B.O.D. and 75% in suspended solids. A pilot plant of the activated sludge type operating on the same wastes produced a maximum average B.O.D. reduction of only 45%.

BY-PRODUCT COKE WORKS: Waste waters containing phenolic and other objectionable substances are produced from stills, gas scrubbers and quenching pits of by-product coke works. The phenolic materials, particularly, are capable of producing extremely offensive tastes and odors, even in very high dilutions, in water supplies derived from streams below coke works. It is possible to eliminate the phenolic bodies in the still waste waters if all the liquid waste is consumed in quenching the hot coke but if there should be drainage from the quench pit it should be returned to the quench tank since the discharge of such liquids would aggravate the pollution. However, coke quenched with still wastes is not acceptable for domestic use because of its odor and dark color. Furthermore, the phenolic bodies which become volatilized in the quenching with still wastes often cause aerial nuisance for a considerable distance.

Several commercial processes are in use for substantial removal of phenols from coke wastes, these involving the use of vapor recirculation processes or of solvents to take up the phenols which are then separated and the solvent material reclaimed for re-utilization. Such systems appear to be capable of reliably removing over 95% of the phenols in the waste waters.

Phenols can be driven off to the atmosphere from gas scrubber wastes by heating to over 300° Fahrenheit.

Objectionable characteristics in coke quenching wastes can be minimized by care in thorough burning of coke to prevent "tar babies" or batches of coke heavy in tar and phenol which would be absorbed by the quench water.

DISTILLERIES: The distillation of fermented grain or molasses leaves still residues which are notoriously high in pollution load. The slop from grain distilleries may have a B.O.D. as high as 30,000 p.p.m., being equivalent to the sewage of a population of about forty people for each bushel of grain consumed or to a population equivalent of ten people for each gallon of whiskey produced. The pollution load from a small distillery of only 1,000 bushels of grain capacity would be equivalent to the sewage of a population of about 40,000.

The slop or still residue is ordinarily screened for the removal of the mash or spent grain which, when dried, is sold as stock feed. The removal of the mash from the slop does not materially reduce the 5-day B.O.D. of the remaining thin slop.

It is quite common at small distilleries to dispose of thin slop by having nearby farmers collect it for hog feed. This method of disposal is rarely, if ever, successful at large distilleries because the distilleries do not ordinarily operate continuously and it is practically impossible to adjust the hog population or slop consuming capacity to the slop production, particularly since the distilleries are either operating full scale or not at all and because some time is required in developing the slop consuming ability of hogs.

The distillery of A. Overholt and Company at Broad Ford, Pennsylvania, has recently installed a waste treatment system comprising: (1) still slop storage tank, (2) Dorr thickener which receives the slop from the still slop storage tank, (3) thin slop tank which receives the supernatant from the Dorr thickener and the thin discharge from a sludge centrifuge, (4) quadruple effect Swenson evaporators which concentrate the wastes from the thin slop tank, (5) Bird centrifuge which receives the settled solids from the Dorr thickener and returns the thin material to the thin slop tank, (6) mixing conveyor which receives the cake from the Bird centrifuge, the syrup from the evaporators and some dry grains for balanced mixture, (7) rotary steam drier which receives and dries the mixture from the mixing conveyor, (8) a blower and piping which conveys the dried grain from the steam drier to storage bins.

Investigation has shown the effluent from the evaporators to be clear and colorless and to have only a slight grainy taste. The results of examination of a sample taken in May 1939 show the condensate or waste from the evaporators to have Methylene Orange Acidity of 17 p.p.m., Phenolphthalein Acidity 172 p.p.m., pH 3.8, and B.O.D. 6.5 p.p.m. Analysis of a composite sample of final waste collected in January 1940 gave Phenolphthalein Acidity 280 p.p.m., pH 3.6, B.O.D. 59 p.p.m., Settleable Solids 0, and Total Solids 60 p.p.m.

"Anaerobic digestion" has been claimed to be capable of reducing the pollution load of distillery wastes by 80% but studies by unprejudiced investigators indicate that the practical improvement by this method would not exceed 60%. No full scale treatment works of this type is known to have been constructed.

Chemical coagulation and sedimentation processes do not appear to be promising for treatment of grain distillery slop because the resultant liquid is still very high in pollution load and the addition of chemicals renders the settled material unfit for reclamation.

The activated sludge process has been proposed but no report of practical performance is available.

The still residues from molasses alcohol distilleries may be even higher in B.O.D. than those from grain distilleries but less is known of them in Pennsylvania because the only ones in this state are at Philadelphia where the waste waters are discharged without treatment to otherwise heavily polluted rivers. However, the characteristic foul odors are at times quite noticeable in the rivers and will undoubtedly require abatement in the not distant future. It is possible to burn the concentrated wastes, after evaporation, to produce potash and this is economically practicable when the price of potash is extremely high, as during the World War. However, neutralization and regulation of flow to a public sewer system and sewage treatment works appears to be logical where sewage flows are very large in quantity and can assimilate the molasses distillery wastes.

MANUFACTURED GAS WORKS: In the manufacture of water gas the principal waste waters are those from the scrubbers in which undesirable materials are washed from the gas before its delivery to the consumer. The scrubber wastes contain oils, tar and complex materials capable of producing objectionable tastes and odors even when quite highly diluted.

The Pennsylvania Gas Association, cooperating with the Pennsylvania Sanitary Water Board, has developed practical methods for treatment of gas works wastes. The step of first importance and that quite generally practiced, although not always with complete success, provides for removal of tar and oils in properly designed and maintained baffled separators and for the re-use of the water from the separators in the gas scrubbers so that there need be practically no discharge. The separators should provide at least three-fourths of a cubic foot of net liquid storage per thousand cubic feet of gas manufactured per 24 hours. The under flow baffles should extend beneath the tar in the bottom of the separator so that this tar will act as an

accumulator to entrain the tar particles in the water passing under the baffle. If dilution in the receiving stream is adequate, more or less of the separator effluent may sometimes be discharged instead of being recirculated although recirculation is sound and economical in principle. It is important that tar sludge and floating oil be removed from the separator at frequent intervals.

The recommendation of the Pennsylvania Gas Association advocates, as a second step, chemical coagulation, sedimentation and sand filtration of separator effluents which contain objectionable tar and oil in suspension. It states that treatment with two pounds of ferrous sulfate and three pounds of lime per thousand gallons of effluent will form a flocculent precipitate which, with sedimentation and filtration, will produce a final effluent entirely free of tar and oil. This method of treatment is practiced at the gas works of the Philadelphia Electric Company at West Conshohocken.

Additional features of the recommendations apply to treatment of wastes which do not respond sufficiently to correction in separators or by coagulation and sedimentation. Tar dehydration by heat and pressure in special apparatus is said to be capable of recovering tar, valued at about 5 1/2 cents per gallon, at a cost of 1/2 cent per gallon. Absorption of phenols in a benzol bath is possible but would be inordinately expensive for the quantities removable from gas works wastes. However, these methods are not known to be practiced in Pennsylvania.

Another danger from gas works is the waste of water used in "purging" or flooding the iron oxide purifiers whose primary purpose is to remove sulfur and cyanogen compounds. These purifiers contain wood shavings impregnated with iron oxide. The purging is necessary to condition the purifiers to permit manual replacement of the spent oxide shavings without danger to the workmen. The purging wastes contain not only the sulphur and cyanogen compounds but also phenols and other complex and objectionable materials. Some success has been attained by coagulation, sedimentation and filtration of the purging wastes but the real solution seems to lie in abandoning the liquid purge and adopting a purge with inert gases to displace the water gas.

The dumping of the spent iron oxide shavings in a manner not to cause pollution is quite important. These waste shavings should be dumped so that rains or surface water will not leach through them to a stream. In at least one gas works the old piles of shavings have been covered with a heavy layer of earth and diversion ditches have been constructed to prevent flooding with surface water.

MILK AND MILK PRODUCTS PLANTS: The handling or processing of milk and milk products usually results in the discharge of relatively large quantities of waste water, although there is wide variation in the quantity and quality of waste waters proportional to the plant production, depending on the availability of water and the management of water-using operations in the plant. Much depends on whether rinse and wash waters of continuous flow equipment are proportional to production, whether or not cooling and condensing waters are recirculated in regenerative equipment and whether by-products such as excess skim milk, buttermilk, whey and spoiled products may be discharged to waste.

The waste waters from various types of milk plants are made up of the spills, drippings and rinsings of containers, utensils, equipment, pipes and floors plus cleaning compounds and incidental chemicals. They are ordinarily slightly acid (pH 6.4 to 6.8) and, in the absence of abundant oxygen in a receiving stream, the lactic acid produced by decomposition precipitates casein which is highly putrescent. A table of analyses of principal milk constituents, as developed by Eldridge (18) is here given:

Average Analysis of Milk and By-Products

<u>Constituents in p.p.m.</u>				
<u>Determination</u>	<u>Whole milk</u>	<u>Skim milk</u>	<u>Buttermilk</u>	<u>Whey</u>
Total solids	125,000	82,300	77,500	72,000
Organic solids	117,000	74,500	68,800	64,000
Fat	36,000	1,000	5,000	4,000
Ash	8,000	7,800	8,700	8,000
Milk sugar	45,000	46,000	43,000	44,000
Protein (casein)	38,000	39,000	36,000	8,000
5-day B.O.D.	102,500	73,000	64,000	32,000
Oxygen consumed	36,750	32,200	28,600	25,900

Average volumes and strength of waste waters, generally not including wasted by-products or cooling and condenser waters, are reported by the U. S. Public Health Service to be approximately as follows:

<u>Plant</u>	<u>Volume</u> <u>Gals. per</u> <u>1000 lbs.</u> <u>milk rec'd.</u>	<u>Total</u> <u>Milk</u> <u>Solids</u> <u>p.p.m.</u>	<u>5-day</u> <u>B.O.D.</u> <u>p.p.m.</u>	<u>Ratio</u> <u>B.O.D.</u> <u>to Milk</u> <u>Solids</u>
Receiving Sta.	160	700	600	0.86
Bottling Wks.	225	600	500	0.83
Cheese Factory	170	-	1896	-
Condensery*	150	1200	800	0.67
Creamery	100	1600	1000	0.67
Dry Milk Plant	150	1200	800	0.67

*Exclusive of pan water; vacuum pan waters run 50 p.p.m. or less B.O.D. and volumes from 1000 to 1500 gals. per 1000 lbs. milk received.

The same source reports the ratio of 5-day B.O.D. to suspended solids in wastes from miscellaneous milk plants to average 1:60.

Surveys in Pennsylvania yield figures of the same order as those shown in the table above, but with wide variations.

Recovery of by-products and "good housekeeping" is of first importance in reducing wastes inside the plant. Following suggestions of H. A. Trebler (National Dairy Products Association) and of this Department, one Pennsylvania general milk plant handling about 50,000 pounds of milk per day, reduced its pollution load about 80%, as measured by representative analytical surveys, by instituting recovery practices and careful housekeeping.

Some practical recovery practices are here listed:

(a) Milk left in cans — When cans are dumped in the receiving room, an appreciable amount of milk is left in the cans which may pass to waste through drippings or can wash water. According to U. S. Public Health Service data this loss may amount to 0.3% to 1.0% of milk intake. An actual measurement made by Pennsylvania Department of Health engineers at a reasonably careful plant showed a loss of about 0.4% due to milk left in the cans after dumping. Trebler (19) has stated that about 4 oz. of milk is commonly left in each can after dumping and that the waste from this source can easily be reduced to 1 oz. or less per can. Eldridge (18) estimates that about 90% recovery is practicable.

Most of the milk lost in this way can be practicably recovered by the use of inexpensive drip-savers and a small high pressure water jet acting as a pre-rinse prior to the can washing, with drainage to the drip-saver pit or collected separately. Health regulations ordinarily prevent

utilization of milk so recovered for human consumption but it should always be possible to provide for its return to the farm for use as stock feed.

(b) Whole milk left in equipment -- Blowing the piping and continuous flow equipment with air, and pre-rinse with small amounts of cold water under pressure, with separate collection of concentrated waste, will prevent much milk from reaching the sewer.

(c) Skim milk -- This should never, under any circumstances, be discharged as a waste. In small plants where it is not economical to produce useful materials from skim milk, it is always possible to develop consumption locally as stock feed. Large plants may economically manufacture chocolate skim milk beverage, milk powder, casein, albumin and lactose. Removal of lactose from wastes prevents development of high acidities which inhibit bacterial activity in biological waste treatment processes.

(d) Whey -- This by-product of cheese manufacture should not be discharged because of high pollution load and bad effect on waste treatment works. It may be dried to become a component of poultry or stock feed. Treatment with lime to neutralize acidity and produce calcium lactate or, after boiling, commercial stock feed is sometimes practiced, with treatment of the supernatant liquor in sand filters. The most common disposal is untreated return to farmers as stock feed or distribution on plowed land.

(e) Buttermilk and butter wash water -- If the demand for buttermilk as such is not adequate, the buttermilk can be fed wet to hogs and poultry or dried by the hot roll method for use in poultry feed. Butter washes are sometimes disposed of as stock feed or irrigation and, in large plants, addition of hydrochloric acid produces a curd which may become a part of poultry feed.

Methods of Treatment

(1) Dilution:

The most elementary method of disposal of milk wastes is by dilution. Frequently milk wastes can be discharged, if dilution is adequate, with no harmful effect but, in fact, with benefit to desirable aquatic life. Regulation of discharge through a holding tank and stabilization by aeration or chlorination during the holding period may aid in disposal by dilution. Ordinarily the dilution requirement for raw milk wastes (without wastes concentrates) will range from 35 or 45 to 1, but under certain conditions a dilution ratio of 100 to 1 may be necessary at all times.

(2) Irrigation:

In isolated or outlying districts small plants may successfully dispose of wastes by intermittent irrigation to loose soil, preferably cultivated periodically.

(3) Imhoff tanks:

Acidity developing during storage inhibits favorable bacterial activity in Imhoff tanks and suspended organic matter, containing fats, does not settle readily as does ordinary sewage. Also, the acidity produces a curd which develops an offensive floating mass. For these reasons, Imhoff tanks are not adapted to milk waste treatment.

(4) Septic Tanks:

Although some authorities contend that the septicization of milk develops products more harmful to streams than fresh milk solids, Trebler (19) states that when strong milk wastes are absent, the proportion of cleaning alkalies to milk sugars becomes larger and favorable septic action develops, particularly if the pounds B.O.D. per unit volume of tank are kept within limits advocated for sewage treatment and the tank is properly seeded. Trebler claims that satisfactory reduction of fat and suspended matter and 30% to 50% B.O.D. reduction may be expected in septic tank treatment. The New York State Department of Health (20) reports reductions of 36% in total solids, 60% in volatile solids, 83% in organic nitrogen, 78% in oxygen consumed and 22% in 5-day B.O.D. by septic tank treatment of milk wastes at Moravia, New York in 1930.

(5) Anaerobic stabilization:

Experiments by Buswell (21) of the Illinois Water Survey indicate that anaerobic digestion of whey and buttermilk is capable of reducing pollution load about 95% with production of 8.3 to 12.4 cubic feet of 550 B.T.U. of gas per pound of milk solids. It is claimed that this method of treatment is quite economical as compared with other methods but there is no record of any actual commercial installation.

(6) Biological filtration:

This is now the most popular treatment process. Reductions of 65% to 70% in B.O.D. have been found possible (Eldridge) (22) in a standard or low rate trickling filter operated at about 1 m.g.a.d. without recirculation on wastes having a B.O.D. of between 500 and 800 p.p.m. and, although earlier investigations indicated that wastes having B.O.D. as high as 800 p.p.m. could be successfully treated at the above rate of filtration, more recent practice favors maximum B.O.D. of applied wastes not exceeding 600 or 700 p.p.m., this to be secured, if necessary, by dilution with clean waste water which would otherwise be discharged without treatment. Agar (20) (New York State Department of Health) reports satisfactory operation

results on single stage filters if rate of application does not exceed 1 pound milk solids per day per 80 cubic feet of filter volume for filters 6 to 10 feet deep. Levine (23) (Iowa Engineering Experiment Station) emphasizes more effective results if wastes are applied frequently in small amounts rather than at longer intervals in large amounts, so favoring the revolving distributor over other distributing devices.

Coarse suspended solids should be removed before filtration, preferably by screening through cheese cloth or fine wire mesh, to prevent filter clogging, and final settling is important for retention of filter sloughings. Filter ventilation is easily accomplished by building filters above ground with woven wire or open joint concrete block, but in cold climates it is considered desirable to build roofs over the filters and close side ventilators in the winter to prevent night freezing. Also, main collecting gutters should be built under the filter or be otherwise protected from freezing during periods of low flows at low temperatures.

Wastes should be applied fresh to trickling filters since stale wastes (unless stabilized) are acid and inhibit biological activity.

B.O.D. removals with various filtering media treating skim milk wastes at a rate of 550,000 g.a.d. on experimental filters 6 feet deep are reported by U. S. Public Health Service as follows:

<u>Filter Medium</u>	<u>B.O.D.</u>			<u>pH</u>
	<u>Raw Wastes</u> <u>p.p.m.</u>	<u>Effluent</u> <u>p.p.m.</u>	<u>Removal</u> <u>per cent</u>	<u>Effluent</u> <u>(raw pH 6.7)</u>
Lath (sectional)*	565	28.9	94.9	7.8
Cinder "	565	13.6	97.6	7.7
Cinder "	508	20.1	96.0	7.8
Cinder (solid)	508	10.6	97.9	7.8
Gravel	513	15.5	97.0	7.8
Spiral rings	513	105.0	79.5	7.7
Corncocks	761	63.0	91.1	8.1
Broken tile	761	31.5	95.6	8.2
Cinder	1000	8	99.2	8.2
Quartzite	1000	144	85.8	8.2

* Six 1-foot layers of lath (or cinders), each separated from the succeeding layer by a 4-inch air space.

Corncocks and cinder do not have long useful life in filters.

Trebler (19) reports the rather surprising removal of 1 pound B.O.D. per day per 8 cu. ft. filter volume using perforated

tin cans as medium in experimental filters, operating three in series with application at a rate of 5 m.g.a.d. and without recirculation.

A filter volume of 80 cu.ft. per pound of milk solids per day applied for filters 6 to 10 ft. deep has been a commonly accepted factor for single stage filters. Eldridge recommends a depth of 8 ft. with the lower foot being of stone 2 to 3 inches in size and the upper 7 ft. being 1 1/2" to 2 1/2" material.

High rate recirculating filters have recently come to the fore and many evidences of their advantages are available. A basic reason for their increased efficiencies appears to be the fact that the pollution load of the effluent (as measured by the B.O.D.) depends upon that of the influent. By diluting an influent of high B.O.D. with an effluent of low B.O.D. and several times its volume, the applied B.O.D. may be reduced to an optimum range for further reduction within the filter. In addition, the recirculating principle insures fair uniformity of applied liquid with absence of shock loads and resultant increase in net efficiency.

H. O. Halvorson, (24) University of Minnesota, by recirculation and ventilation, secured reductions of 85% to 95% in treatment of milk wastes having B.O.D.'s of 2500 to 3000 p.p.m. For very strong milk wastes he found it advantageous to allow the wastes to sour first, with resultant precipitation of casein, and to apply the soured supernatant (pH 4.5) as mixed with recirculated effluent of pH in excess of 7.0.

Eldridge (23) finds that the number of cycles through a filter is more important for filter efficiency than is the loading (B.O.D.) and that a given number of cycles will produce about the same result, regardless of raw strength applied. By test runs on an experimental filter he found that by recirculating 8.3 times a milk waste of, originally, 714 p.p.m. B.O.D., it was possible to reduce the pollution load 83.5% with a filter volume of 21.5 cu.ft. per pound B.O.D. applied, this being effected at a total treatment rate of 2.4 m.g.a.d. and a recirculated applied rate of 20 m.g.a.d. High rate trickling filters appear to be capable of B.O.D. reduction equivalent to that of standard trickling filters between two and three times their volume and this indicates that existing standard filters may safely be increased in capacity or efficiency by providing recirculation.

For small milk plants with waste volumes limited to several thousand gallons daily, Eldridge (7) (23) suggests fill-and-draw treatment on a trickling filter, reporting reductions in B.O.D. ranging from 47.4% on raw wastes averaging 508 p.p.m. B.O.D.

recirculated four times, to 98.3% on raw wastes averaging 1780 p.p.m. B.O.D., recirculated thirty-three times. He advised a plant comprising a hopper bottom tank of capacity equal to maximum daily volume of wastes, a small pump, rotary distributor and a filter 6 to 7 feet deep and of area to provide 1 sq.ft. surface area per 30 to 35 gallons waste per day with rate of application about 20 to 25 gallons per sq.ft. per hour. The tank would be emptied each morning and filled during the day while waste is being continuously applied to the filter. Sludge, if in considerable amount, should be withdrawn from the hopper bottom to a sludge pit before drawing off the treated waste.

Eldridge and others indicate that sedimentation, after filtration, of not less than one hour and preferably two hours for peak volumes must be provided to precipitate the flocculated material produced and rather continuously unloaded from high rate filters.

Activated Sludge

There are several adaptations of the activated sludge principle which have been made applicable to milk waste treatment. Among these are the so-called Guggenheim Process, the Mallory Process and the American Solvent Recovery Process.

The Guggenheim Process consists of coagulation with hydrated lime and ferric sulfate followed by about 4 hours aeration of the mixture of the treated raw waste and returned sludge from a secondary sedimentation basin providing two hours detention. In a pilot plant operated over a period of three months it was indicated that the best results were obtained by the use of 100 p.p.m. lime and 40 p.p.m. ferric chloride. With aeration period of 2.2 to 4 hours and settling time of 1 to 2 hours, a reduction of 89.2% was effected in B.O.D. of raw wastes averaging 400 p.p.m. B.O.D. The volume of air used averaged about 2.4 cu.ft. per gallon of waste treated.

At a cheese factory at Glen Karn, Ohio, (24) receiving 20,000 to 40,000 lbs. milk per day and producing 6,000 to 14,000 g.p.d. of wastes averaging 600 to 2,000 p.p.m. B.O.D. (except when whey discharges increase B.O.D. about tenfold) this treatment process effects average reductions in B.O.D. of 92.3%, total solids 50%, volatile solids 76.7%, suspended solids 93% and total nitrogen 47.5%.

The principal difficulty in this treatment process appears to be that of disposal of the sludge which is difficult to digest or to dry on sludge beds and which constitutes about 1% of the total waste volume.

The American Solvents Recovery system as installed at New Bremen, Ohio, and Somerset, Pennsylvania, is a quite conventional activated sludge process, preceded by lime treatment for conversion of lactic acid to calcium lactate. At Somerset (25) where the daily milk intake is 60,000 pounds, the waste treatment units comprise a receiving well, lime mixing chamber (with air agitation), primary settling basin, aerating basin and final settling basin. The total capacity of all units is 86,400 gallons, providing total detention period of 36 hours for the 50,000 g.p.d.* average discharge. The mixing basin and primary settling basin each provide detention of about 3 hours, the aerating basin about 24 hours and the final settling basin about 6 hours. The lime dose averages about 1 pound per thousand gallons and the air used is about 2.8 cu.ft. per gallon of waste. The only sludge removed regularly is that from the primary settling basin in amount of about 500 gallons per day or about 1% of the total volume treated. All sludge from the final settling basin is recirculated to the aerating basin and appears to become ultimately entirely liquified. Tests show that this plant reduced B.O.D. from 545 p.p.m. to 7.4 p.p.m. and population equivalent from 1400 to 18, or 98.4%. Total reduction was from 797 p.p.m. to 466 p.p.m. or 42%, these data being the averages of periodic studies at this plant during three years.

The Mallory System, as installed at Doe Run, Pennsylvania, is a factory built assembly utilizing a primary and a secondary tank, of steel construction, with conical bottoms. The primary tank contains a steel cylinder to provide an inner and an outer compartment. Air is applied near the bottom of the outer compartment of the primary tank and the inner compartment, also equipped with an aerator, acts as a clarifier. Sludge is returned to the primary tank from the secondary tank. The effluent from the primary tank passes to an influent mixing compartment in the secondary tank, where alum and lime are added, consecutively. The effluent from the secondary tank passes down a so-called "hydraulic cascade" tube (of questionable importance). Sludge is removed for final disposal from both the primary and secondary tanks and constitutes from 1% to 2% of the total waste volume. The overall detention period of the plant is of the order of 24 hours and, with the B.O.D. load, of applied wastes over twice as great as the design capacity (25 pounds B.O.D. per day), the plant was found to reduce an influent B.O.D. of 1127 p.p.m. to 86 p.p.m. or 92.3% and it also reduced volatile suspended solids from 520 p.p.m. to 17 p.p.m. or 96.7%.

* Note: Information received since writing above indicates no clean cooling or other waste waters in appreciable quantity are discharged to the waste treatment works but that abundant water supply induces extravagant consumption with excessive quantity of waste water to treatment works as compared with an average plant.

OIL PRODUCTION FIELDS: There are in Pennsylvania approximately 100,000 oil wells, these being scattered rather widely west of the Allegheny Mountains. In the production of oil, the oil and salt water pumped from the wells is discharged to flotation tanks from which the supernatant oil is pumped to pipe lines leading to refineries or shipping points and the residual brine is wasted. It is not practical to remove completely all crude oil from the flotation tanks prior to wasting the brine and some oil is frequently discharged to waste with the brine. Obsolete equipment and human carelessness contribute to the still considerable waste of crude oil to Pennsylvania streams, even though a favorable differential in the price of Pennsylvania crude has done much to reduce previous wastes.

Oil discharged to streams not only creates unsightly stream banks but imparts objectionable tastes and odors to the water, adheres to suspended particles with resultant compacting and other difficulties in water filters and is directly destructive to fish and plant life in streams.

It is possible to prevent the discharge of oil from the production fields by the exercise of great care in the flotation process and by providing an auxiliary separating basin at each separating tank, or group of tanks, to prevent accidental spills from reaching streams. However, because of the great number, wide distribution and inaccessibility of oil wells in the state, a program of pollution control from these sources would require a large staff of inspectors and great expense.

In certain production fields in the southwestern part of this country oil well brines are disposed of by evaporation and absorption in large lagoons constructed in sandy or porous soil. Topography and soil conditions do not ordinarily favor such disposal in Pennsylvania.

In other parts of the country it is common to require disposal of brine by return to the ground through non-productive wells. In fact, such practice is routine in parts of Pennsylvania and New York where "repressuring" is economically necessary to make oil available at the producing wells, but repressuring is restricted by statutes to part of the Bradford Field and certain adjacent areas. However, State Geologist George H. Ashley states that return of brine to the earth through non-productive wells would not be interpreted by him as unlawful unless the definite purpose were to repressure nearby producing oil wells. Therefore, the return of brine to underground measures appears to offer a definite possibility in cases where the discharge of brine to streams causes distinctly harmful pollution.

In some instances abandoned wells produce a free flow of brine and it is therefore important that all non-productive wells be tightly capped or plugged.

PAPER AND PULP MILLS: The kinds of paper manufactured in Pennsylvania mills include bond, book, magazine, parchment, tissue, towels, wrapping, board and roofing felt. The waste common to all these products is known as "white water" which is the liquid waste from the paper making machine and contains short paper fibers, and possibly, "size" and mineral filler, as well as suspended dirt and dissolved organic matter in the case of mills making paper board from dirty old paper such as cartons, newsprint, magazines, etc.

The fibers lost in white water, being cellulose, are decomposable and impose a considerable pollution load when discharged. Furthermore, the wasted fibers sometimes form septic sludge deposits in streams and these may be scoured out by suddenly increased stream velocities with a resultant wave of pollution.

The practicability of using efficient save-alls or other means for removal and re-utilization of fibrous material and a considerable part of filler, if present, is now generally recognized. Many mills recirculate practically all white water to beaters, head boxes and top showers, but rarely can such waste water be successfully used in the felt showers since the felts must be kept clean and free from slimes.

Save-alls are of three general types: screen, sedimentation and flotation. The screen save-alls may be of the "hillside" (fixed inclined), rotary or vibrator type. The most efficient of these appear to be the so-called vacuum filters which are of the rotary type with very fine mesh wire and reduced pressure inside the cylinder. The ordinary rotary screen save-all with wire of usually 40 to 60 mesh is not particularly efficient although fair results are sometimes secured by "sweetening" the applied white water with new pulp to build a filtering mat on the screen.

The sedimentation type save-alls are similar to conventional clarifiers with mechanical equipment for removal of settled solids and they are particularly applicable in handling white water, containing large quantities of mineral filler, such as in the manufacture of book and magazine papers.

Flotation save-alls, such as the Adka and Sveen-Pederson, employ the principle of flotation of coagulated matter with entrained air. Glue and some proprietary mucilaginous compounds, as well as the more common water coagulants, are used in these processes. The diffused air is introduced near the point of application of the chemicals to the influent water. In the Adka save-all the entire top of the tank is sealed and partial vacuum maintained over the liquid, the floating solids are removed by vacuum through a revolving surface skimmer and the clarified water is withdrawn from the bottom of the tank. In the Sveen-Pederson save-all the principle of flotation is the same as applied

in the Adka with the exception that the vacuum feature is omitted and the floated material is drawn over a weir by mechanical skimming flights.

Tests of the efficiency of Adka save-alls indicated reduction of 82% in volatile suspended solids and 64% in B.O.D. in a "fine paper" mill. In a felt mill the reductions were measured as 43% in volatile suspended solids and 58% in B.O.D. Some tests of a Sveen-Pederson save-all handling white water from the manufacture of glassine paper showed reductions as high as 95% in volatile suspended solids and 36% in B.O.D. but much lower efficiencies were indicated in tests made at other times, possibly due to lack of experience in control.

Certain paper mills, particularly those manufacturing tissue, towels, board and felt, are able to re-utilize white water without high degree treatment, requiring only effective disinfection to prevent slime growths.

In general, the so-called closed system required a tank of ample capacity to receive and hold white water for recirculation, and with provision for adding fresh water automatically if the demand is greater than the white water supply. If this tank is apt to overflow, means should be installed for treatment of this overflow to the degree required, to prevent harmful pollution.

The periodic clean-up of paper mills, either between runs of different colors or simply before shut-down periods, is often the cause of extremely heavy pollution of short duration since much pulp may be wilfully discharged. An ordinary pollution survey of a paper mill during a period of normal operation would not disclose the clean-up pollution and it is necessary to measure this load during the clean-up period.

A number of pollution surveys at typical paper mills in Pennsylvania indicate that practically every paper mill can, without hardship, for each ton of product, restrict its waste white water volume to less than 10,000 gallons, fiber losses (volatile suspended solids) to less than 1/2% or 10 pounds, and B.O.D. to a value not exceeding 5 pounds. This is equivalent, in B.O.D., to a maximum population equivalent of 30 per ton of paper produced.

If satisfactory reduction in pollution load of white water cannot be attained by adoption of a closed system, or if the mill in question does not wish to adopt such a system, it appears logical that final treatment before discharge should be required. Experience indicates that plain sedimentation for a theoretical period of 12 to 24 hours, with regulation of rate of discharge and facilities for removal of settled solids at

sufficiently frequent intervals to prevent septic disturbance, effects fair removal of volatile suspended solids but not a great reduction in B.O.D. Chemical coagulation and sedimentation for 12 to 24 hours in basins without means for continuous or frequent removal of settled solids, but at times when accumulated sludge was not excessive, has been found to reduce volatile suspended solids 55% and B.O.D. load 70% at one board mill in Pennsylvania. It appears safe to assume that chemical coagulation and sedimentation for a theoretical detention period of, say, 4 hours in well designed basins equipped for mechanical removal of settled solids should be capable of producing satisfactory results in practically all cases, but it would seem advisable to base approval of such proposed treatment on pilot plant operation or, at least, on a series of laboratory tests.

A number of paper mills de-ink magazines and similar used paper to produce a pulp which is mixed with new pulp in the manufacture of magazine and some book paper. The de-inking process involves the use of strong chemicals such as caustic soda and the waste waters produced are very high in pollution load. No conventional method for treatment of these wastes appears to have been developed, but chemical coagulation and sedimentation have been shown to be effective although expensive. At Johnsonburg the de-inking wastes and wash waters from the used paper department are impounded in a reservoir having a capacity 60 times the daily discharge and the effluent flows thence 1.4 miles down a steep channel to the river. The raw wastes average about 60 p.p.m. B.O.D. and 250 p.p.m. alkalinity (M.O.) with pH values between 7.0 and 8.0. The wastes entering the river average about 14 p.p.m. B.O.D. and 6 p.p.m. D.O.

Pennsylvania mills producing pulp from wood utilize either the sulfite process, the soda process or a variation of the latter, for removal of the lignins and other undesirable substances from the clean fiber. In ordinary practice, over half the weight of the wood is washed out with the waste waters.

Sulfite pulp mill wastes are a most serious problem in stream pollution. They are large in volume, somewhat acid, have a very high oxygen demand, are high in color, produce objectionable tastes and odors and, unless highly diluted, render a receiving stream unfit for water supply purposes, fish life or recreational uses.

At a large pulp mill in Johnsonburg there has recently been installed, at great expense, a system for concentrating the waste liquor, treating it for sulfur recovery, evaporating to a thick syrup and burning under the plant boilers. This system functions well except for production of a very fine fly-ash which settles in the vicinity and produces a distinct nuisance. The mill management has had combustion experts study this fly-ash problem but, as yet, it has not been solved. The company has

been able to sell a part of the alkalized sulfite wastes in syrup form for road binder and some other uses but the intermittent discharge of the wastes for which there is no market or means of combustion still constitutes a serious pollution problem.

The "Howard Process" for treatment and utilization of sulfite wastes as operated at Rothschild, Wisconsin, is somewhat similar in principle to the "Johnsonburg Process" and is claimed to be capable of reducing stream pollution from this source by 75%, but it is reported that the market for by-products produced there from the sulfite wastes is so limited that great quantities of the dried crude wastes are accumulated and, also, that considerable untreated wastes are discharged. If the Johnsonburg mill solves the combustion problem the pollution abatement there will be about 85% since only dilute pulp wash water, containing about 15% of the sulfite liquor, will be discharged untreated.

The waste liquor from soda pulp mills is not as difficult to treat for removal of objectionable characteristics as is that from sulfite pulp mills and recovery of by-products for re-use or sale is common practice. Drainage and rinse waters from blow pits, known as black liquor, are ordinarily concentrated in evaporators, burned in rotary kilns for removal of resinous material and the resulting black ash leached for recovery of sodium carbonate which is calcined with quick lime (calcium hydroxide) for conversion to caustic soda for re-use. The calcium carbonate (lime sludge) resulting from this reaction is recalcined to produce quick lime for re-utilization. The black ash, or carbon from the burning of the black liquor, remaining in suspension after the leaching process is sometimes discharged without treatment but in some mills it is recovered for conversion into activated carbon. At the Tyrone mill of the West Virginia Pulp and Paper Company, a Filtration Engineers, Inc. string filter removes carbon from waste waters to reduce a former discharge of 6,000 lbs., carbon per day to about 100 lbs. per day which is not discernible to the eye in the clear water discharged.

Bleach liquor from the chlorine (gas or hypochlorite) bleaching of wood pulp is recorded as having B.O.D. values ranging between 20 p.p.m. and 2,200 p.p.m. At Johnsonburg where the waste waters are in amount of 800 gallons per ton of sulfite pulp bleached, the B.O.D. of the wastes was found to be 2,200 p.p.m. and at Tyrone where about 2,300 gallons of waste were discharged per ton of soda pulp bleached, the B.O.D. of the wastes was measured as 136 p.p.m. A practical method of treatment of such wastes is not yet known to the writer, but back cycling of the bleach rinse waters is desirable to reduce the quantity of discharge so that the problem of treatment may be simplified.

A few mills in Pennsylvania produce pulp by digestion of rags or old rope with a caustic solution. The wastes from such

a process are extremely high in pollution load. Two small mills are entirely disposing of rag digester wastes by discharge to leaching pits but, because of the jelly-like deposit produced, it is doubtful if such method will prove permanently satisfactory unless occasional complete cleaning or construction of new leaching basins is a practical solution. One mill attempted to evaporate digester wastes for recovery of caustic but found that foaming in the multiple effect evaporator could not be successfully controlled. A mill which digests old rope, after indifferent results with acid coagulation, has met with rather marked success by calcium chloride coagulation of the wastes in batch or fill-and-draw treatment, with absorption of the clarified or supernatant liquor in loose gravel soil and drying the settled sludge in a sludge bed in natural formation.

PETROLEUM REFINERY WASTES: Because of the character and complexity of petroleum refinery wastes, the removal or control of objectionable characteristics of waste waters requires special studies by persons intimate with refinery processes and practices. The reports and publications of the American Petroleum Institute, through its Committee on Disposal of Refinery Wastes, are recognized as the most authoritative source of information on this subject and should be consulted in any petroleum refinery waste problem. Also, certain recent papers of W. B. Hart (Atlantic Refining Company, Philadelphia) amplify features of A.P.I. bulletins and discuss developments of research since the date of A.P.I. publications.

The character of wastes from refineries may be classified as follows:

1. General: Combined wastes may contain crude oil or any of its fractions and suspended mineral and organic compounds in waste liquors and sludges from various processes.

2. Oil: May be present as free oil, emulsified oil or coating on suspended matter (Waste waters ordinarily contain less than 0.01% oil).

The relation of thickness, appearance and quantity of floating oil on water is given in the following table:

Approx. thickness of film--inches	Appearance	Approx. quantity (gals.) oil for a spread of 1 sq.mi.
0.0000015	Barely visible under most favorable light conditions.	25
0.000003	Visible as silvery sheen on surface.	50
0.000006	First trace of color may be observed.	100
0.000012	Bright bands of color are visible.	200
0.000040	Colors begin to turn dull.	666
0.000080	Colors are much darker	1,332

It has been found that films of oil uniformly 0.000003 inches in thickness (50 gals. per square mile) did not persist on the average for more than 5 hours on an agitated water surface, this disappearance being due to the operation of natural phenomena which are but vaguely understood.

Emulsions of simple or complicated type may appear as turbidity, usually of milky appearance but sometimes of dark color. Emulsions ultimately become free oil.

Oil as coating on suspended matter may float persistently as an oily sludge and, from effects of wind or freshets, it may settle and later release oil to the surface over a long period of time.

3. Substances other than oils: These include true solutes, suspensoids and emulsoids of more or less complicated structure and they may be produced from almost any unit of a refinery. They include acids, alkalies, inorganic salts, phenolic compounds, naphthenic acids, organic nitrogen compounds (pyridines, amines, etc.), organic sulfur compounds (mercaptides, etc.), clay, and many other materials, some of which are distinctly objectionable even in high dilution.

Analytical data concerning quantities and characteristics of refinery wastes are not plentiful and do not appear to be consistent, probably because of the varying processes employed and the differences in the crudes treated. However, grab samples have indicated sewage population equivalents of about 1,600 per 1,000 barrels of crude oil refined per day.

In addition to the obviously objectionable effects of wasted oil, refinery wastes may discharge phenols which produce chlorophenol tastes in concentrations as low as 0.002 to 0.005 p.p.m. when the water bearing them is chlorinated. The complex organic sulfur compounds, principally from caustic wash water, produce persistent and objectionable tastes and odors, it having been found in Pennsylvania that such wastes are detectable when diluted one part in ten million parts of odorless spring water. It is reported that ethyl mercaptan produced a detectable odor in a concentration as low as one part per fifty billion.

Remedial measures advocated by the American Petroleum Institute for control of the commoner wastes are outlined as follows:

1. Reduce oil loss by:
 - (a) Good housekeeping.
 - (b) Minimizing formation and breaking of emulsions.
 - (c) Removal and reclamation of oil in gravity separators.

2. Remove settleable solids in separators and settling basins.
3. Isolate at their source the wastes containing the more objectionable constituents and provide special treatment or reduce or regulate the discharge to within the limit of tolerance.

The tendency to recover valuable materials or by-products from refinery wastes is growing, particularly among the larger refineries where skilled laboratory control of complicated processes can be practiced. Some of the more common recoveries are:

1. Sulfonic acid,--from acid tar residuals of sulfuric acid treatment.
2. Petroleum coke,--from destructive distillation of crude bottoms and acid sludge.
3. Aromatic hydrocarbons and derivatives,--when economically competing with coal tar sources.
4. Naphthenic acids,--from caustic wash waters.
5. Sulfuric acid,--recovered from acid sludge for re-utilization.
6. Oil,--from separators returned for re-run process.

Gravity separators are commonly used for oil recovery and removal of settleable solids. A.P.I. bulletins consider separator design in detail and indicate that units providing average velocities not exceeding 2 feet per minute, partition velocities not exceeding 4 feet per minute and detention period of at least 60 minutes should produce an effluent containing not more than 0.003% oil (30 p.p.m.).

Recent studies of separator design as conducted by W. B. Hart, (26) used as the basis of design of a new separator at the refinery of the Sun Oil Company at Marcus Hook, are very illuminating and the more important features developed are here abstracted from a paper by Mr. Hart.

For best separation the pH should ordinarily not be lower than 4.5 or higher than 10.0. High dissolved solids may affect gravity and should not exceed 1,000 p.p.m. Most effective application points for baffles or weirs are at the inlet and outlet zones, leaving an undisturbed space in the main body of the chamber for gravity differential to exert full play. Any columns, supports or other structural features in the water body, should be designed in "stream line" cross section in the direction of flow, with ample radii where necessary. Best results in filtration of separator effluent through closely woven cloth, such as flannel, for removal of oil whose gravity is nearly the same as that of water, are obtained at a rate not exceeding 0.5 cu.ft. per sq.ft. per minute, but rate must be

adjusted to retain an almost balanced head on both sides of filter. Separators 6 to 8 feet deep, rather than deeper, are desirable. Separators should not be made so narrow, in relation to length, that a velocity in excess of 3 to 4 feet per minute is developed. Cascade of the separator effluent tends to release odors and also may cause absorption of considerable oxygen. The warmer the water the better the separation. A lighter oil may be added to the liquid under treatment to produce an average gravity which will cause improved separation. The capacity of a separator should not be set at the normal process load only, because of storm water and fire stream run-off, but should be effective over a wide range. A "flight-scraper" device should be installed in the first stage of a separator to keep the sedimentation chamber clean and ample filtering should follow the second stage. The visual test for fluorescence of effluent is the most valuable one to gage the effectiveness of an oil separator. A turbidity test of 25 p.p.m. as shown by the Jackson turbidimeter, will indicate a clarity in which emulsions and colloids are at a minimum.

The separator design recommended by Mr. Hart, comprises two units of approximately equal size and proportion, in series. Each stage provides an influent surge chamber communicating with a grid-bottomed cell, filled with broken stone and with accumulated oil mass, for film-rupture, coalescence and distribution to sedimentation compartment, and a single scum baffle immediately in front of an outfall weir. The first stage has added to it a flight-scraper cleaning device, sludge collecting sump and an oil-skimming slotted pipe with tilting device. A final stage may provide a submerged cloth screen to further remove fine particles of oil which are not readily separable by gravity, this screen to be continuously cleaned by water jets under 25 to 30 pounds pressure. If only light oils are to be handled, separate from heavier products, the influent stone cell should be omitted but the cloth filter should be added. Rounding of corners and weirs are considered advisable to reduce eddy currents and increase efficiency.

Special separators for easily broken emulsions (naphtha treating and tank bottoms) can be made by providing a cascade followed by sedimentation. The more stable emulsions should be broken before reaching the separator, by means which can be devised only by considering each emulsion as an individual problem. (See--American Petroleum Institute, "Disposal of Refinery Wastes -- Section I -- Waste Water Containing Oil.")

For control of objectionable refinery wastes, other than oil, the following is abstracted from A.P.I. bulletins:

Mineral Acidity and Alkalinity: It is important that anticorrosion activity be controlled in the operation of crude

and re-run stills so that the waste waters therefrom will always be slightly alkaline.

Acid sludge should be handled in a closed system without drainage to the plant sewers. Sludges may be burned in a furnace for simple disposal or they may be treated for recovery of acid with incineration of final residues. Stack gases from sludge burning may be treated consecutively in a water scrubber and an oil scrubber for removal of sulfur dioxide and malodorous gases, the water scrubber waste being later subjected to limestone contact or lime treatment for reduction of acidity and the oil scrubber waste being burned.

Acid waste waters may be segregated and used for neutralizing highly alkaline wastes, breaking emulsions and diluting in sludge separating operations, or they may be neutralized before discharge.

Alkali treatment processes produce wastes objectionable because of high alkalinity and tastes and odors. Special measures to eliminate or prevent the escape of tastes and odors may be adopted for neutralizing acid waste waters but must be carefully controlled to prevent formation of emulsions.

Hydrogen Sulfide and Sulfide Solutes: Residues of these sulfides from fractionation processes may be removed by treatment with caustic soda but further treatment of the caustic sludges is necessary to control tastes and odors. Shallow lagooning is sometimes practiced to provide oxidation and evaporation. Treatment with heat and air or with stack gases is sometimes practiced but the gases formed must usually be burned in a furnace.

Oxygen Consuming Compounds: Identification of the source of the high oxygen consuming wastes is important. The difficulty then may be controlled by modification of process to eliminate the objectionable characteristics, recirculation over cooling towers or contact aerators, segregation and lagooning or chemical treatment.

Tastes and Odors: Of first importance is a survey to identify the individual sources of the objectionable constituents, to be followed by their segregation for control. Waste caustic solution is the most common offender and may be treated by acidification, removal and burning of the resultant oily layer containing phenolics and, if further reduction of phenolic content is necessary, by extraction with oil, followed by final disposal of the water portion of the separation by dilution. Aeration prior to final discharge may also be necessary. A patented process (U.S. Pat. No. 1,667,550) for litharge recovery (doctor solution) is also applicable to treatment of these wastes.

Waste waters, if acid in reaction and carrying taste and odor producing compounds, may be used for acid sludge separation in place of fresh water or may be neutralized with alkaline waste and transferred to an alkaline waste process.

In general, wastes from other processes can also be treated by measures similar to those outlined, for reduction in taste and odor producing constituents. Ponding, regulation of discharge and dilution, or recirculation in a closed system, are recommended as worthy of first consideration in all cases.

Total Solids: The A.P.I. recommendation for control of excessive total solids consists of segregation of concentrated wastes from major contributing processes, followed by storage and regulation of discharge to take advantage of dilution during periods of high water in the receiving stream.

PLATE GLASS WORKS: The manufacture of plate glass utilizes great quantities of fine sand for surface grinding, this sand being wasted in water after it has become so worn that it is no longer sufficiently abrasive. If the wastes are discharged to streams without treatment, the fine sand will cause deposits and may render the receiving stream decidedly turbid for a considerable distance.

Sedimentation in large "slush ponds" has been found effective for removal of most of the sand from the wastes, although the smallest particles do not settle readily and may cause local turbidity in the receiving stream. Since slush ponds are not effective unless quiescent sedimentation is afforded it is important that provision be made for proper removal of deposited solids and it would seem that sedimentation tanks with mechanical sludge removal devices would offer more positive treatment. The principle of treatment is practically identical with that of anthracite culm and silt with somewhat longer detention periods seemingly required for the sand wastes.

This problem is not frequently met with because plate glass works are relatively few in number but it is nevertheless of occasional importance.

QUARRIES AND SAND WASHERIES: In the preparation of sand and stone for construction and industrial purposes large quantities of water are used to remove dirt, clay and undesirable fine particles. The waste waters as discharged do not contain appreciable amounts of decomposable material but they cause heavy deposits and turbidity.

Where space is available it is possible to remove most of the objectionable sediment and turbidity in slush ponds, but finely divided clay does not settle readily and may cause long-lasting turbidity even though no appreciable deposits are formed by the wastes. Long-time impoundage in lagoons or in abandoned portions of quarries has proved to be quite a satisfactory solution but care must be taken to remove settled solids or provide new basins when the old ones become filled with solids.

Jar tests on typical crushed sand washery wastes indicate that most of the settleable solids are precipitated in quiescent sedimentation of 1 hour, leaving a supernatant liquid still very turbid with noticeable suspensoid particles; that sedimentation for 2 hours compacted the settled solids and produced a supernatant still quite turbid but somewhat transparent; that 8 hour sedimentation produced slightly more settled solids than the 2 hour test with a fairly clear and transparent supernatant. Assuming from the classic experiments of Capen (14) that well designed and proportioned sedimentation basins are approximately 1/4th as efficient as absolute quiescence in laboratory jar tests, it appears that suitable basins of 4 to 8 hours detention period, with ample allowance for accumulated settled solids, should ordinarily afford sufficient treatment. If turbidity in the receiving stream, as well as deposits therein, are the cause of complaint it would be well to require long-time sedimentation.

One large sand washery, having a normal waste discharge of 4,800,000 gallons in a 20 hour working day, has installed a treatment works comprising a pumping station, a Dorr clarifier of 175,000 gallon over-all capacity providing 0.73 hour theoretical detention, and a 23 acre sludge pond surrounded by dikes 10 feet high. The total cost of installation was given as \$58,000 and the annual operating cost is estimated at \$19,700. The efficiency of the treatment works in removal of total solids is between 70% and 80% with the final effluent carrying a maximum of approximately 4,000 p.p.m. total solids and showing little improvement in appearance over the untreated wastes.

TANNERIES: The principles of treating tannery wastes, as developed by the Tannery Waste Disposal Committee of Pennsylvania with cooperation of the Sanitary Water Board and described in a bulletin issued in December 1930, (27) are still generally recognized as standard. An abstract of these principles and description of their application in conformity with more advanced equipment than was in common use in 1930 has been prepared by F. B. Milligan, who compiled the original report, and is here given:

An average tannery in Pennsylvania uses the vegetable tanning process and handles about 25,000 pounds of hide each

day, producing approximately 7 gallons of waste water per pound of hide. Of this volume, about 7% is sludge with an average moisture content of 95% by weight. A few plants use the mineral tanning process, in which the tanning agent is chrome alum. At the single plant studied, the wastes averaged 12 gallons per pound of hide and contained 3% to 4% sludge by volume.

The volumes and characteristics of the waste waters vary widely. Those from the cleaning and unhairing of hides carry mud, lime, particles of flesh and hair. Spent liquors from vegetable tanning and bleaching vats contain complex and colored organic material. The total wastes are high in suspended, colloidal and dissolved solids, color, odor and oxygen demand. Mineral tanning wastes are similar but carry much less organic material and are lower in color and oxygen demand. It has been claimed that such wastes have a bactericidal effect which may interfere with biological treatment processes, and the natural self-purification of streams. Experience in Pennsylvania indicates that in ordinary dilution, no markedly detrimental effect occurs.

The table on page 38 contains volumes and analyses of wastes from a number of Pennsylvania tanneries.

Methods of waste treatment have been devised in successive steps, each giving an added amount of purification to meet various conditions, and applicable both to vegetable and mineral tannery wastes. After the establishment of the first step, its actual effect should be studied before additional treatment is required. The several steps involve briefly:

- (1) Mixture of all wastes, sedimentation with removal of sludge, and discharge of the settled liquid at a uniform rate throughout the 24 hours.

- (2) Separation of spent tanning liquors, small in volume but high in putrescibility and color, their storage during months of low stream stages with slow controlled discharge through months of high water. In some cases the spent tans are evaporated and sold.

- (3) Aeration by means of trickling filters with resettlement preceded in extreme cases by chemical coagulation.

Step (1) may be expected to give 90% to 95% removal of settleable solids and a 40% to 60% reduction in B.O.D.

The addition of Step (2) will generally result in 95% to 100% removal of settleable solids and 70% to 85% B.O.D. reduction when spent tan liquors are stored. Later controlled discharge of these liquors will increase the pollution load in the receiving stream, but only at times of much higher stream flows.

Steps (1) and (2) are now in routine use in Pennsylvania. Step (3) was tested at full scale but is not in regular service.

The most acceptable plant for Step (1) in the light of experience to date should comprise:

A raw waste sump and non-clog pump.

A combined mixing and fill-draw settling tank rectangular in shape, ratio of length to width as 4 or 5 is to 1, depth 6 to 10 feet, overall capacity 1 to 1 1/2 times the daily waste volume, equipped with paddle-type mixers, mechanical sludge scrapers of any standard type for moving the wet sludge to hoppers connected to sludge pumps, suitable influent ports for raw waste, and with horizontal perforated float-supported pipes acting as outfall weirs and discharging through swinging draw-down pipes, and pump or gravity control-box, to a secondary tank. The mixing paddles should be operated slowly while raw wastes are entering the tank, or about 8 hours daily. After a 7-hour period of quiet settling, the partially settled wastes should be withdrawn to the secondary tank, leaving a 2-hour period for removal of the sludge when necessary.

The secondary tank should be of the variable-level type equipped with horizontal float-supported swinging influent pipes arranged to distribute the influent as evenly as possible across the width of the basin with minimum turbulence and foaming. Similar float-supported collector pipes should be connected by swinging draw-down pipes to float valve and control-box for discharge of the final effluent, 22 to 24 hours per day, to sewer or stream. The dimensions of the secondary tank should duplicate those of the primary tank. It should be furnished with mechanical sludge-removal devices for use as required when the tank is idle. Only relatively small quantities of sludge ought to reach this tank.

Where sludge is removed by hand the most satisfactory layout consists of three tanks or earthen lagoons operated in rotation on the fill-draw principle, one being always out of service for cleaning. The tanks should be proportioned about as outlined in the preceding paragraph, except that depths may be 4 to 12 feet. The capacity of each tank should equal one day's waste volume plus 35% for sludge storage; there also should be one similar secondary tank for equalization of flow and resettlement of the cloudy material which is apt to be withdrawn as the sludge line is approached.

Sludge can be handled in various ways:

(a) By sludge-drying beds having surface area of one square foot for each pound of hide processed in the tannery per day. The beds are not underdrained since this has proved of small value, but skimmer pipes are used for the removal of rain water and re-settled top water. These are usually led to the raw waste sump. The wet sludge, average moisture content 95%, should not exceed two feet in depth. When dried to 80%

moisture this is removed from the beds with shovels and wheelbarrows and may be used as fill or as fertilizer. There is an average lime content of 10%, but little nitrogen or phosphorus.

(b) By piping the wet sludge to large storage lagoons where it can dry over a period of years and eventually be removed by power shovel and truck, or by hauling the wet sludge in tank trucks directly to a dump. Both these methods are in current use.

(c) By use of centrifugal sludge driers. Equipment for handling all sludge in this fashion has been installed by one large tannery and placed in trial operation. Conclusive performance data are not yet available, although preliminary reports are promising.

For storage of the spent tan liquors during summer months as listed under step (2), lagoons in simple excavation are satisfactory. Their capacity should be 300 to 400 gallons per pound of hide per day and they should be equipped with swinging draw-down pipes and discharge-control valves. No other apparatus is required and cleaning and operating costs are almost nil.

It is unfortunate that the color even of adequately treated vegetable tannery wastes is high, due to the presence of spent tan liquor. In fact, oxidation unless almost complete, develops darker shades of color. This color is not in itself ordinarily harmful to users of the water but is a common cause of complaint and, also, the color in the stream is claimed to obscure sunlight and retard the growth of aquatic oxygen-producing plant life which is largely responsible for natural purification of streams. Treatment of tannery wastes nevertheless greatly shortens the distance through which discoloration persists in the receiving stream.

RAW TANNERY WASTES DATA

Vegetable Tanning Process

NO.	POUNDS GREEN SALTED HIDE PER DAY	DATE	WASTE VOLUME GAL- LONS PER DAY	TOTAL SOL- IDS PPM	SOL- UBLE SOL- IDS PPM	SUS- PEND- ED SOL- IDS PPM	VOLA- TILE SOL- IDS PPM	FIXED SOL- IDS PPM	pH	5 DAY BOD PPM	POP- ULA- TION EQUIVA- LENT	COLOR A.P. H.A.
1	36000	1929 -31	283000	9827	5696	4131	4488	5339	9.5	1281	18142	3400
2	20000	1935	92800	13980	9750	4230	5081	8899	9.3	1672	7755	8000
3	18000	1933	69100	5236	3787	1449	2049	3187	9.9	603	2080	1150
4	22500	1932	285167	3677	2564	1113	1065	2612	11.0	519	7420	4150
*5	15000	1931	160000	4714	2422	2292	2670	2044	7.3	1460	11680	5000
6	19500	1929	85700	9557	4983	4574	5359	4198	8.3	1221	5230	7250
**7	35500	1935	324000	11198	7583	3615	5892	5306	7.4	1903	30820	3750
8	14500	1932	153000	7010	4856	2154	2865	4145	9.8	688	5260	4250
9	21000	1931	110000	10970	8940	2030	5440	5530	7.8	1490	8190	5900
10	25000	1932	126000	7467	4229	3230	3871	3596	10.3	1523	9590	4180
11	22500	1932	82650	14702	9405	5297	5001	9701	9.6	2082	8605	3950
*12	4700	1932	32765	3238	1619	1619	1746	1502	9.4	1223	2006	5550

AVERAGES (FOR 11 TANNERIES):

21063 138092 9337 6017 3320 4393 4944 8.7 1441 9942 4450

Mineral Tanning Process

13 10500 1930
-31 130000 10846 5212 5635 2752 8094 9.8 300 1950 200

4 Large part of spent tan liquor evaporated. B.O.D. and other analyses therefore not representative and not included in averages.

* These tanneries produce "light" leathers for sporting goods, luggage, etc. All other tanneries listed produce "heavy" leather for shoe soles and power belting.

** Tannery operating at 67% of total capacity.

4 Tannery operating at 40% of total capacity.

TEXTILE MILLS: The treatment of textile wastes is a particularly difficult problem because rarely do two textile mills follow identical practices and, also, the processes and resultant character of wastes of a single mill frequently change from day to day. The variations in the character of textile wastes require not only different types of treatment works at different mills but also different operation of such works at different times.

In a paper published in "Industrial and Engineering Chemistry", (November 1939), C. R. Hoover, (28) of the State Water Commission of Connecticut, includes the following table which emphasizes the variability of textile wastes:

Oxygen Demand and Population Equivalent of Textile Plant Composites and Typical Variations

<u>Nature of Process</u>	<u>Approx. No. of Workers</u>	<u>pH</u>	<u>5-day B.O.D. p.p.m.</u>	<u>Gals. of Wastes per Day</u>	<u>Population Equivalent*</u>
Cotton thread (bleach, kier, oil, dye)	150	3.3 9.0	550 378	40,000 19,000	1,093 357
Finishing cotton piece goods (bleach, kier, dye, print)	120	9.6 6.9	605 420	274,000 180,000	8,239 3,745
Finishing cotton piece goods (bleach, kier, mercerize, print, dye)	220	9.8 7.6	478 315	438,000 360,000	10,405 5,635
Cotton webbing (bleach, kier, dye, impregnate)	750	11.1 6.3	1983 245	220,000 80,000	21,682 974
Silk (degum, bleach, dye, print weave)	2500	4.6 7.0	462 360	1,200,000 700,000	27,554 12,600**
Rayon (knit, bleach, dye, size)	250	7.0 2.5	1920 183	125,000 115,000	11,928 1,046
Wool (scour, weave, dye, finish)	200	11.7 8.1	936 540	120,000 120,000	5,582 3,221
Felt from scoured wool	100	1.5 5.3	138 370	30,000 75,000	206 1,379

* Basis: 5-day B.O.D. of 0.167-lb. oxygen requirement of domestic sewage from one person for 24 hours.

** This value for Population Equivalent calculated by Pennsylvania Department of Health. All other Figures in table quoted as given by Hoover.

In addition to substantially confirming the data in the above table, Robert Spurr Weston (3) reports the B.O.D. of wool scouring wastes as 4,000 to 10,000 p.p.m., of cotton and rayon finishing wastes as 390 p.p.m. and of laundry wastes as 154 p.p.m.

Methods for treatment of general or combined textile wastes are as follows:

Segregation: A large part of the wastes from a textile mill are relatively clean wash or rinse waters and can often be assimilated in a stream without harm. The remaining strong wastes, being relatively small in volume, are usually capable of final treatment in a smaller and less expensive treatment works, although some dilution with the weaker wastes may sometimes be desirable for chemical or biological reasons. Also it may be desirable to provide preliminary treatment for certain particularly strong wastes such as from wool scouring or sulfur dyeing.

Objections to segregation are the difficulties and cost of installing dual drainage systems and dependence on workers of questionable reliability for operation of such a dual system. It is reported that an interlocking device is available for batch processing which makes it possible to prevent the discharge of wastes from a dye or rinse vat to the strong waste drain when clean water is flowing through the vat for rinsing but provides that when dye wastes or strong wash waters are discharged and clean water is not circulating through the vat the wastes pass to the strong waste drain. If counter-current washing is practiced only small volumes of strong wastes are produced and segregation is not applicable.

Equalization: Mixing of all wastes, allowing opportunity for dilution and helpful mutual reaction, with regulation of discharge over as long a period as possible, is simple, inexpensive and often affords sufficient treatment to permit discharge to a stream or to a public sewer system with treatment works. Such equalization is also important as a feature of more refined waste treatment since it is obviously most difficult to effectively treat a waste which changes in character every few minutes. Equalization or mixing tanks providing capacity for the discharge of an entire day are desirable and usually provided in treatment works at mills of ordinary size but authorities claim that satisfactory operation can usually be obtained with smaller equalizing tanks, a capacity of about three hours flow being the absolute minimum. If fill-and-draw tanks are used the same tanks can serve for averaging, mixing, coagulation and sedimentation. Equalization of characteristics is more difficult in a continuous-flow tank, because of "piston-action" through the tank and, for this reason, agitation or flow distribution devices appear necessary.

The simplest device for regulating the final discharge consists of a floating arm take-off which, in itself, can be made to approach the equivalent of constant-head orifice box by proper adjustment of the discharge openings, although a constant-head orifice box is usually desirable.

Screening and Aeration: Removal of fibers by screening may be necessary to protect filters or public sewer systems but, ordinarily, is not important in waste treatment since fibers become a part of sludge or scum in sedimentation tanks.

Aeration has been recommended for oxidation of wastes containing reducing agents, such as sulfur dyes, preliminary to subsequent treatment. The most common method is by introduction of diffused compressed air at the bottom of the equalizing tank or in the fill-and-draw treatment tank prior to addition of chemical coagulants. Geyer and Perry, (29) in their report on a survey made for The Textile Foundation, state that aeration is important as a final treatment in cases where the treated effluent is low in oxygen.

C. R. Hoover (28) urges aeration for its chemical and physical effect, as distinguished from biological oxidation alone, since it accelerates storage and equalization effects and converts emulsions into removable scums. His tests indicate better efficiency with diffused compressed air than with sprays or mechanical aerators. He reports as high as 70% oxidation can be brought about through solution aeration involving combined chemical, physical and biological action.

Precipitation: The benefit of mutual reaction or coprecipitation of alkaline and acid wastes has been mentioned above as a feature of "equalization" but this effect, although helpful, is rarely productive of a sufficient degree of treatment.

Chemical precipitation is recognized as the most important and generally accepted method of treating textile wastes, being considered capable of ordinarily removing 80% to 90% of oxygen consuming material from the stronger wastes (B.O.D. of 800 p.p.m. or over) and approximately 60% from the weaker wastes (B.O.D. of 200-300 p.p.m.).

Difficulty in chemical coagulation and precipitation may be encountered due to excessive quantities of soapy water or of wastes containing gums, resins, waxes, sulfonated oil or other substances which form only a light precipitate which will not settle readily. Weighting the precipitate with clay or using heavy metal coagulants is desirable in such cases. Also, separate treatment of particularly offending waste constituents may be most effective and economical.

The practical coagulants ordinarily used, for combined effects, are ferric and ferrous sulfates, chlorinated copperas and ferric chloride, activated carbon, sodium aluminate, aluminum sulfate, clays and sodium silicate. Acidifying reagents are sulfuric acid, chlorine and sulfur dioxide. Lime is the standard alkalizing reagent. Calcium chloride is a useful source of the essential calcium ion in alkaline or neutral wastes.

No one method of treatment or any single test for determination of effective treatment can be relied upon. Frequent and continuing tests must be made to determine, by actual experiment, the kind and quantity of each chemical to be added and the best point for its application. Treatment with metallic salts followed by lime is usually but not always preferable to the reverse. Proper pH is important and, in some instances (soluble oils or soaps), a two-step or two-pH coagulation is desirable. Solution feed is preferable to dry feed of chemicals. Air agitation of coagulating mixtures is considered advantageous for periods over 30 minutes if ferric salts are used but less effective than mechanical stirring with aluminum sulfate and copperas. In general, violent agitation with either air or a mechanical propeller should be followed by a period of slow stirring or "rolling".

Regardless of the chemical treatment, the tanks or basins will be of rather conventional type. The fill-and-draw type of tank appears to be decidedly the best for equalizing, chemical reaction and sedimentation, and it is always preferable at small plants. However, for large volumes of wastes and for establishments requiring large equalizing basins for blending of wastes, continuous-flow treatment may offer economies.

Two hours should be a sufficient time to settle a good chemical floc in a tank 10 feet deep to 2% or 3% of the volume treated, although capacities of much more than the volume of plant wastes discharged over such a period are essential since time must be allowed for mixing, batch testing, chemical dosing and mixing and floc formation and, also, at least 25% surplus tank capacity should be provided for sludge accumulation. Retention of sludge in fill-and-draw tanks is often advantageous, it being indicated that substantial savings in chemicals and better coagulation can be effected by permitting four or five re-uses of sludge and withdrawing only from 20% to 25% of total sludge accumulated after each batch treatment.

Continuous flow sedimentation tanks should be discouraged but, if at all justifiable following equalization, they should be carefully designed to prevent short-circuiting and disturbances of uniform velocity due to poor influent and effluent distribution or to temperature changes. Also, a continuous flow tank should be provided with positive means for removal of sludge with a minimum of water content.

Mechanical filtration of the supernatant liquor from sedimentation tanks is sometimes practiced but does not appear to be particularly effective or justifiable if coagulation and sedimentation are as effective as they should be.

Sludge may sometimes be disposed of by lagooning, if local conditions are peculiarly favorable, but it is customary to provide sludge drying beds similar to those used in sewage treatment practice. C. R. Hoover (28) states that an acre of undrained earth lagoon will care for the sludge from 150,000 gallons of waste per day and that an acre of underdrained sand beds is adequate for 500,000 gallons per day. General practice indicates that sludge should be applied to drying beds to a depth not exceeding 12 inches and that it can be removed when it has dried to 90% or less in water content. Care should be exercised in maintaining a clean and undiminished sand surface on the sludge bed.

Biological Action: Although rather extensively used in Great Britain, biological treatment of textile wastes has not yet become popular in this country. However, the occasional need for high degree treatment may require the adoption of biological processes. Bio-filtration or trickling filters appear to be the most effective means of providing aerobic action. Sand filters have a history of becoming rapidly clogged when treating such wastes. Straining filters do not appear capable of providing the nitrate formation essential to purification. Concentrated textile wastes, when mixed with 80% to 90% domestic sewage will respond satisfactorily to trickling filter treatment. After preliminary equalization and sedimentation, average textile wastes in such dilution may be treated on trickling filters with a reduction of B.O.D. as high as 90% at a cost comparable with that of treating domestic sewage alone.

Miscellaneous Treatment: A few special methods are here outlined for treating specific wastes which may prove troublesome in the general treatment of mixed wastes.

Kier liquors are ordinarily best treated in mixture with other wastes but may require separate treatment as with flue gas or by dialysis through a selective membrane for recovery of caustic. The last-named method has recently given quite definite promise of economic success.

Silk degumming liquor, if not assimilable in mixed wastes, may be separately coagulated and precipitated, or treated with mineral acid for recovery of oils and fatty acids of considerable value.

Bleaching wastes, if kept separate from deterging wastes, are easily treated by chemical precipitation with an iron salt and lime.

Sulfur dye wastes are best treated with ferric chloride followed by acidification with hydrochloric acid. It is reliably reported that sulfur dye waste can be purified by the activated sludge process when well diluted with domestic sewage.

Wool scouring wastes are particularly difficult to treat because of high grease content. The practice of degreasing wool by chemical solvent processes, with recovery of both lanolin and solvent, is growing and should be encouraged, but in all probability, some grease will be present in final wool scouring wastes. Supercentrifuges are successfully used in grease recovery, particularly in conjunction with counter-current washing processes which conserve soap. Acid cracking for removal of grease, prior to subsequent treatment, is rather common. Aeration and chlorination, or a combination of both, has been the subject of much recent study in a search for a more satisfactory method of grease removal, but an entirely successful application of these agents has not yet been developed.

VEGETABLE AND FRUIT CANNERIES: The canning industry has grown rapidly in Pennsylvania during recent years and gives promise of further development. Many crops are canned and the processes involved usually produce waste waters both large in volume and high in pollution load. Since many canneries process both vegetables and fruits and the wastes therefrom are of much the same general nature, the treatment of these wastes is considered as one subject. Purposely excluded from particular consideration herein are the establishments which prepare pickles, relishes, preserves, soups and other similar articles, because they produce waste waters of a considerably different nature and are, usually, located in large centers of population where the waste water problem is likely to become a part of the public sewerage problem.

The vegetable and fruit cannery wastes which are of most common interest, in the approximate order of their seasonal production, are peas, cherries, string beans, lima beans, tomatoes, corn and apples. Some canneries, such as those canning solely corn, operate for only five or six weeks each year and it is difficult on an economic basis, to justify the installation of expensive waste treatment works for use over such a short period of time, even though the waste waters may be extremely high in pollution load and discharged during a season of low stream stages and high temperatures when pollution effects are intensified. Other canneries may operate more or less continuously for periods of six or eight months each year, beginning with peas and continuing with root crops and soaked dried peas and beans well into the winter season. These latter general canneries should be better able to afford the installation of more elaborate waste treatment works.

As in the consideration of all waste disposal problems, it is most important that canneries organize their processes, with the rigid application of "good housekeeping" practices, to segregate the solids as much as possible, preventing their addition to the liquid wastes, and so reducing the difficulties and costs of liquid waste treatment. Skins, parings, pomace and culls can usually be disposed of to advantage by feeding to hogs but, if not, by spreading in fields as fertilizer.

Even with extreme care in exclusion of solids from waste waters through good housekeeping practices, cannery waste waters will include a sufficient quantity of solids to justify screening for removal of solids preliminary to whatever method of waste treatment may be adopted. Screens should be of 40 mesh wire, or equivalent, even though some cannery operators contend that such fine screens can not be kept clean. If the screens are of the rotary type with suitable water sprays, or the vibrator type, properly designed and installed, they can be operated to minimize the solid content of the waste waters and so simplify the liquid treatment problem. The screenings, averaging about 90% in moisture, can usually be disposed of as hog feed or fertilizer.

Incidental to the canning of peas, lima beans and corn, the vines or husks are stacked and produce stack liquor or ensilage juice which is extremely high in pollution load. W. A. Ryan (30) of Rochester, N.Y., reports typical analytical characteristics of these wastes as follows:

STRENGTH OF ENSILAGE JUICE FROM PEAS,
CORN AND LIMA BEANS

Results Reported in Parts Per Million

	Pea Ensilage Juice	Corn Ensilage Juice	Lima Beans Ensilage Juice
Suspended Solids.....	Trace	Trace	Trace
Dissolved Solids.....	87,156	46,690	47,250
pH value.....	5.0	4.5	5.2
Biochemical oxygen demand 5 days.....	41,500	27,000	25,200
Oxygen consumed.....	28,000	15,000	13,000

These figures are sufficient to indicate that stack juices or ensilage waste would impose a heavy burden on any waste treatment process. It is highly desirable that pea and bean vines be spread on fields, particularly if vining is carried on in the field. Otherwise, the stacks should be located on dry and

porous soil with a deep trench encircling the stack to provide for absorption into the soil. Corn husks and cobs are not considered suitable for spreading on fields when fresh and should be stacked, with protective absorption ditch, until in a sufficiently decomposed condition to be suitable as fertilizer. C. A. Holmquist, (31)(32) New York State Department of Health, reports that treatment of pea vine stack liquor with 100 pounds of lime per thousand gallons will reduce its organic content 80%.

Some typical analytical characteristics of cannery wastes as listed by Mr. Ryan here follow:

SCREENED WASTES THAT DO NOT CONTAIN
ENSILAGE JUICE

Results in Parts Per Million

<u>Screened</u>	<u>Corn Waste</u>	<u>Pea Waste</u>	<u>Tomato Waste</u>
Suspended solids.....	1740	272	430
Dissolved solids.....	4625	6452	2277
pH value.....	5.4	4.4	5.0
Biochemical oxygen demand 5 days.....	3500	2500	1190
Oxygen Consumed.....	3650	2900	1558

Average analytical data of straight run cannery wastes as reported by the U.S. Public Health Service are summarized as follows:

	<u>Corn Wastes</u>	<u>Whole Tomatoes</u>	<u>Tomato Products</u>
5-day B.O.D. in p.p.m. ...	623	4000	1000
Suspended solids in p.p.m.	240	2000	500
Dissolved solids in p.p.m.	1270	-	-
pH.....	6.3	-	4.8 to 8.4
Oxygen consumed in p.p.m.	970	1360	-
Gals. waste per case			
No. 2 cans.....	25*	7.5	60

* Not including cooling and condenser water which will average about 20 gallons per case.

Comparison of the data on corn waste in the above table with available information on Pennsylvania corn canneries leads to the assumption that the U. S. Public Health Service data relate to canneries in which cream style corn is prepared, whereas most of the Pennsylvania corn canneries now prepare the newer

style whole-kernel corn. In this process the bleeding of the cream from the kernel is minimized by the special cutting process and the juices adhering to the kernels are washed away and to waste, so making the waste waters much higher in pollution load than those from cream style corn canneries.

Analyses of representative screened wastes from typical canneries in Pennsylvania show wastes from peas to have a B.O.D. of about 750 p.p.m. and settleable solids about 4.5 c.c. per liter; from corn (whole-kernel style) a B.O.D. varying from 1020 to 4900 p.p.m., and settleable solids from 23 to 190 c.c. per liter; from whole tomatoes a B.O.D. of 788 p.p.m. and settleable solids 52 c.c. per liter; from tomato products a B.O.D. of 178 to 419 p.p.m. and settleable solids 17 to 38 c.c. per liter; from string beans a B.O.D. of 67 p.p.m. and settleable solids 2.5 c.c. per liter; and from apple sauce a B.O.D. about 1700 to 3500 p.p.m. and settleable solids 75 to 160 c.c. per liter. These figures show considerable variation from those reported by others and illustrate the range in analytical characteristics of waste waters which may be expected from different canneries, due to the differences in processes followed. Consequently, in considering suitable methods of waste treatment for any cannery, it is important to have full knowledge of the quantity and character of the waste waters.

It has been found by a number of reputable investigators that the cooling waters, in which the cans after sterilization are immersed, are ordinarily quite clean and may be discharged without any treatment whatsoever.

The methods of cannery waste treatment, after screening, which are more or less commonly practiced are:

1. Impounding lagoons.
2. Chemical coagulation and sedimentation.
3. Continuous trickling filters with sedimentation and recirculation.
4. Preliminary sedimentation and intermittent sand filtration.

In locations where sufficient space is available and nuisance from odors is not an important factor, lagooning or impounding is frequently successful and economical for the cannery of short seasonal operation. Lagoons for this purpose should have a maximum working depth of about 2 feet and should have strongly constructed and impervious walls or dikes. If the basins are of sufficient size to retain the polluting wastes of the entire season of operation, the wastes can sometimes be disposed of during the remainder of the year by absorption into the soil and evaporation. Diversion ditches should be provided to prevent surface water from flowing to the lagoons. Pumping settled wastes

from lagoons to irrigate cultivated fields may be practiced to increase the working capacity of lagoons or prepare them for reconditioning in the following season. The bottoms of lagoons should be scraped clean, to fresh earth surfaces, before the beginning of each season of operations to stimulate absorption into the soil.

One Pennsylvania cannery has been experimenting with preliminary chemical coagulation and sedimentation in one lagoon with discharge thence to other basins for retention until regulated discharge can be resorted to during periods of high stream flow when dilution is favorable.

Chemical coagulation and sedimentation has been practiced with varied success in Pennsylvania and other states, the chemicals used being, usually, ferrous sulfate and lime, sodium aluminate and lime, and lime alone. The dosage can be determined only by experiment and may require frequent change to meet the varying characteristics of the wastes. Corn wastes have, so far, not been found amenable to satisfactory chemical coagulation by either the Pennsylvania Department of Health or G. C. Scott (33) of Minnesota Valley Canning Company, probably due to the approximate 2% starch and 1/2% sugar content of wastes from canneries packing whole-kernel corn. The concensus of opinion indicates that wastes from peas, beans, tomatoes, apples or cherries may be more or less effectively treated by chemical coagulation using 5 to 10 pounds lime and 1 to 6 pounds ferrous sulfate or alum per 1,000 gallons of waste, and settlement in well designed basins of capacities equal to 4 times and preferably 8 times the average hourly waste flow.

L. F. Warrick, (34) (35) Wisconsin State Board of Health, reports that the 5-day B.O.D. of pea canning wastes, in volume about 1 gallon per each No. 2 can packed, can be reduced in the range of 50% to 75% by fine screening and chemical coagulation with 3 1/4 pounds ferrous sulfate and 7 1/4 pounds lime per 1,000 gallons, followed by thorough mixing and sedimentation for at least one hour. Comparable and more recent chemical treatment and sedimentation of pea wastes, after screening, was found to reduce B.O.D. of the screened wastes between 32% and 69%. Daily removal of sludge is essential to maintain this efficiency and to permit rapid drying on sand beds without odor. Mechanical rotary screens with 40 mesh wire are also a necessary feature of this treatment. Fill-and-draw type tanks are favored over those of the continuous flow type, although the latter type was reported by Warrick in 1936 to have been successful at one cannery.

Warrick (35) further reports, with respect to cannery wastes in general, that six passes of screened waste through a trickling filter of 2 1/2 to 3 inch stone, 8 feet deep, with application rate of 20 m.g.a.d., reduced the B.O.D. of beet waste 60%, of corn waste 70% and of tomato waste 73%. Settling of the filter

effluent for one hour in a suitable tank further reduced the oxygen demand 10% to 14%. With pea wastes he found that 63% recirculation through a rock filter produced B.O.D. reductions between 37% and 59% and that subsequent sedimentation provided further reduction about equivalent to that obtained as above noted with other cannery wastes.

C. A. Holmquist (32) reports that a sludge bed area of 3,000 square feet is needed to dry sludge resulting from chemical coagulation of 100,000 gallons of cannery wastes, based on a 7 day drying period and application of sludge to a depth of 3 feet, and that half of this area is adequate when sludge is previously dewatered, by sedimentation and decanting, in separate tanks having capacities equal to 10% of that of the coagulation and sedimentation tanks. To secure satisfactory drying at this rate, he recommends treatment of the sludge with sufficient lime to produce a pH value in excess of 10.0.

Experiments conducted in 1936 by the Indiana State Board of Health (36) indicated: that fine screening and chemical precipitation will provide sufficient treatment for cannery wastes discharged to streams affording reasonable dilution; that such treatment will in many cases serve as sufficient pre-treatment for cannery wastes discharged to municipal sewage treatment works; that filter media of size from 2 1/2" to 4" did not clog in filters operating at a high rate, although smaller stone did clog; and that the increased efficiency of the high rate filter, when operating at a return ratio of three to one, rather than a return ratio of one to one, does not apparently justify the additional cost.

E. F. Eldridge (37) of the Michigan Engineering Experiment Station states that the volume of waste water, exclusive of clean water, from a full-line cannery may average from 25 gallons per case of No. 2 cans to as high as 200 gallons, depending upon products canned and the size of pack. For such mixed wastes he advocates fine screening followed by treatment in a trickling filter at an applied rate of about 1 m.g.a.d. but data on efficiency are not reported. He also advocates screening followed by chemical coagulation and sedimentation for treatment of tomato wastes and pea wastes, recommending a detention period of 15 minutes in the coagulation or mixing tank, with a sludge bed area of 75 square feet per 2,000 gallons waste flow per hour, all based on maximum hourly flows.

William A. Ryan (30) indicates that cannery waste load can be handled in a municipal sewage treatment works if the wastes are not greater in quantity than 20% of the combined flow, particularly if the pH of the cannery wastes has been raised to 8.0 by addition of lime.

Studies recently conducted by H. O. Halvorson (38) and associates of the University of Minnesota, under the auspices of the Minnesota Cannery Association, developed data showing that corn wastes vary in B.O.D. from 1200 to 4000 p.p.m., in total solids from 1500 to 8000 p.p.m., total volatile solids from 1400 to 7000 p.p.m., and suspended solids from 300 to 4000 p.p.m., with reaction about neutral when fresh but developing pH as low as 3.5 on standing. Exclusive of silage stack juice, it was found that from 0.4 to 0.5 pounds B.O.D. was produced per case of 12 oz. (No. 2) cans, with the volume of waste varying from 30 to 40 gallons per case of No. 2 cans. These ranges cover both cream-style and whole-kernel corn, with the latter producing the greater pollution load and, inferentially, also the greater quantity of waste per unit of production.

These investigations showed that chemical treatment of corn wastes is not yet a satisfactory solution. It was found that one passage of undiluted corn waste through a trickling filter, at a rate of 20 m.g.a.d. produced a reduction in B.O.D. of about 25%, that dilution of influent with effluent incident to five-time recirculation resulted in B.O.D. reduction of about 50%, that increasing recirculation to ten times increased B.O.D. reduction to about 60% and that good results may be expected from the use of a trickling filter in treatment of combined sewage and corn wastes if the volume of the latter does not exceed that of the former.

Further investigations were made under the direction of Halvorson (39) with yeast wastes having a B.O.D. of 2,000 p.p.m., a pH of 3.5 and organic matter in solution very high. High rate filtration with continuous recirculation was found to be only about as successful as with corn wastes and could not, alone, be considered a satisfactory solution.

The wastes were then lagooned and, after six months in storage with practically no measured change in pollution strength, they were treated in a trickling filter designed for an applied rate of 20 m.g.a.d. and a total treated rate which each day handled 1/7th of the total volume stored. Two weeks operation raised the pH in the lagoon to about 7 and continuously dropped the B.O.D. After three months operation, the B.O.D. of the accumulated wastes was reduced from 2400 to 200 p.p.m. and the B.O.D. of settled filter effluent was about 100 p.p.m., with the troublesome odor nuisance minimized. This led to an operating schedule of continuous recirculating filtration and daily final discharge of filter effluent in amount equal to the average daily influent to the lagoon. Recent information from Halvorson indicates that odors from lagoons can be controlled and a satisfactory effluent produced by circulating not less than 10% of the stored volume through a trickling filter at an applied rate of 20 m.g.a.d. and continuing the treatment until the desired reduction in pollution load has been attained.

The success of this treatment of yeast wastes led to laboratory scale experiments with similar treatment of corn wastes with results showing reduction of B.O.D. of lagooned wastes from 2500 to less than 100 p.p.m. in a period of fourteen weeks. Consequently, Halvorson proposes this as a practical and economical treatment of the wastes from the short seasonal operations of corn canneries, as well as for other cannery wastes, and suggests that a filter having a daily capacity of 10% of the lagoon capacity can reduce the B.O.D. of corn wastes to below 100 p.p.m. in less than ten weeks, so that the entire contents of the lagoon could, by October 1, be safely discharged into a stream. Of course, this could be done at whatever rate might seem desirable under any particular set of conditions.

Wastes from a Pennsylvania cannery packing whole-kernel corn have been treated with promising success in a plant providing fine screening, one hour plain sedimentation, intermittent sand filtration at a rate of about 100,000 g.a.d. and drying of settled solids on a sludge bed having area 10% of the intermittent sand filters. An efficiency of 85% in reduction of B.O.D. (raw B.O.D. average 4900 p.p.m.) was measured in this plant but the two filters finally became matted with starch jelly which would not dry rapidly enough for removal. One additional filter (50% increase in present filter area) would probably make the treatment plant sufficiently flexible to operate successfully over the entire 5 or 6 weeks of the corn canning season but it is doubtful if treatment of this type would be suitable for strong full-line cannery wastes over a long season because of cumulative clogging of the filters without sufficient rest periods for decomposition of the clogging materials.

Another Pennsylvania corn cannery operating a high rate trickling filter at an applied rate of 14 m.g.a.d. which provided average recirculation of 3 1/2 times, with sedimentation of 2 1/4 hours theoretical detention period, was found to be capable of reducing the B.O.D. of the raw wastes (average B.O.D. 2,000 p.p.m.) an average of about 55% although, at times, the efficiency was measured as low as 17%. Particular difficulty is to be expected in effectively seeding a trickling filter preparatory to a short and intensive canning season.

Based on observations of cannery waste treatment works in Pennsylvania and on reports of results elsewhere, the following table is presented to show approximately the efficiencies which may be expected from well designed and operated vegetable cannery waste treatment works of several types:

CANNERY WASTES

Effects of Various Steps in Waste Treatment

Type of Treatment	B.O.D. Reduction		Settleable Solids	
	Influent to Effluent of Treatment Units designated in left hand column	Total Reduction from un-screened Raw Wastes for Units designated, plus all preceding units	Unit Influent to Unit Effluent	Total Reduction from Raw Wastes
Screening	10% to 30%	Ave. 20%	20% to 60%	Ave. 40%
Plus Chemical Coagulation plus Sedimentation (For Apple Wastes)	20% to 60%	Ave. About 60% 80%	80% to 90%	About 90% 95%)
Screening, Trickling Filtration, and 5 times Recirculation with Sedimentation		40% to 80% Ave. About 65%		About 95%
Screening, Sedimentation, Intermittent Sand Filtration. (For Corn Wastes)		About 85%		About 95%

WOOD DISTILLATE PLANTS: The distillation of hardwood was at one time a very important industry in Pennsylvania but, principally due to the development of synthetic processes for production of acetone, methanol and acetic acid, this industry had almost disappeared a few years ago. However, there has been some recent revival of the industry due to improvement in by-product recovery and, since the wastes from wood distillate plants are notorious because of their toxicity to fish life and their ability to impart very objectionable and persistent odors to the receiving stream, this paper would not be complete without some reference to the control of pollution from these so-called "chemical plants".

The common products of the distillation of hardwood are charcoal, pyroligneous acid and wood tar. The refining of pyroligneous acid produces methanol (methyl alcohol) acetone and acetic acid, with some less important substances. The waste waters from these processes include some pyroligneous acid, acetic acid, wood tar, creosote and various combination products, depending on the process followed at any particular plant.

Experiments with typical wastes from a wood distillate plant manufacturing principally methanol, showed that several varieties of fish died in a very short time when placed in a 1% concentration of the wastes and that some fish were noticeably affected over a longer period of time in a concentration of only 0.2%.

It is entirely practicable to remove tar from the wastes by simple sedimentation separators and to dispose of it by burning under the boilers.

There is no known successful method of chemically or biologically modifying the objectionable pyroligneous and related compounds so that they can be safely discharged to streams. For this reason, these wastes must be kept out of the streams by complete destruction or by retention in lagoons for final disposal by evaporation and absorption into the soil.

At one large plant in Pennsylvania, manufacturing methanol, the still wastes have been evaporated to dryness in open pan evaporators and the dry cake disposed of as fill at a point where it will not leach to a stream.

Many of the wood distillate plants formerly producing methanol have been converted to produce acetic acid by a direct process which practically eliminates pyroligneous acid in the waste waters, but dilute acetic acid, of strength insufficient to justify economical recovery, is commonly discharged and may cause harm to fish life. Also, accidental spills from such plants have on occasions caused considerable damage.

The only safe rule to follow in the disposal of waste waters from wood distillate plants, regardless of the process engaged in, is to build bigger and better lagoons and to insure that they are properly maintained to prevent leaks and flooding by surface water.

Many other kinds of industrial wastes not considered in this paper may appear as unusual and special problems requiring individual study. Some of these problems may be solved by modification of processes within the manufacturing plant and others will prove incapable of solution with present knowledge. Also, the installation of the most soundly designed waste treatment system will not abate pollution if the treatment plant is not operated efficiently and with scientific control.

In concluding this paper it seems proper to summarize the steps which should be followed in solving any major industrial waste problem, as follows:

1. Demonstration of the magnitude and effect of pollution.
2. Detail study of the processes and waste waters as a basis for process changes or design of treatment works.
3. Design of treatment works by engineers of ability and experience who will employ the most modern and effective principles with proper regard to economy in construction and operation.
4. Honest and durable construction of treatment works in strict accordance with the design as approved.
5. Development of pollution consciousness on the part of the owners or mill management to such a degree that proper supervision and control of operation of waste treatment works will be provided.
6. Repeated inspections and analytical studies of waste treatment works to maintain a sense of responsibility on the part of the works management, discover and correct troublesome discharges due to process changes, aid in improvement or economy of plant operation and, finally, find

facts which will be useful for purposes of comparison and in the solution of other similar or related problems.

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